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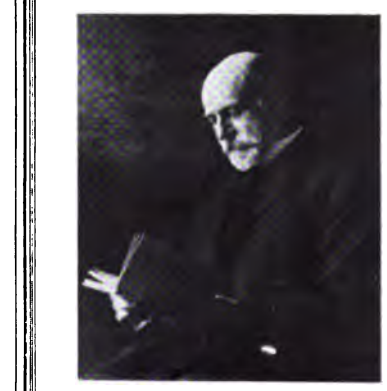

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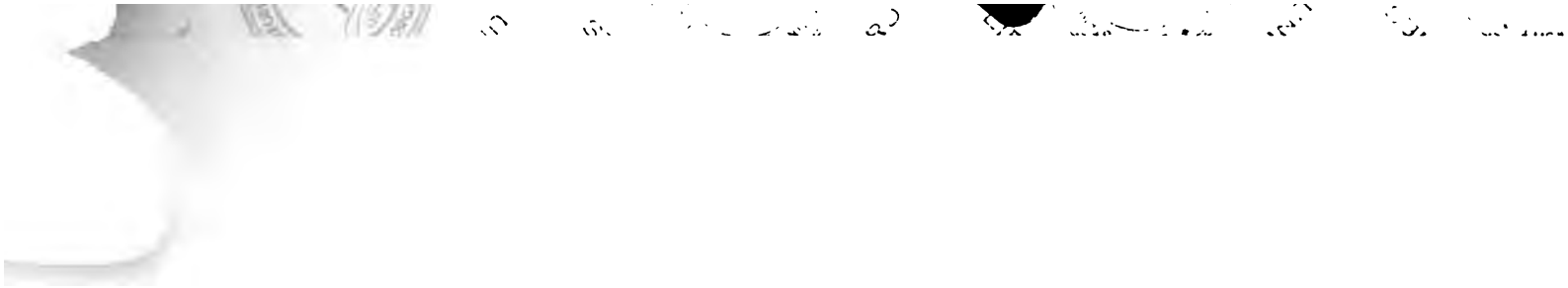

WISCONSIN GEOLOGICAL AND NATURAL HISTORY SURVEY
E. A. BIRGE, Director. W. O. HOTCHKISS, State Geologist.

BULLETIN NO. XXIII. ECONOMIC SERIES NO. 14

RECONNOISSANCE

SOIL SURVEY

STANFORD UNIVERSITY
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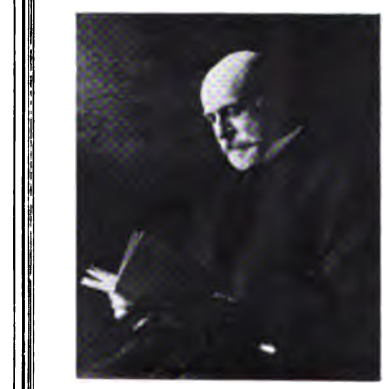

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RECONNOISSANCE SOIL SURVEY OF NORTH WESTERN WISCONSIN.

CHAPTER I.

GENERAL DESCRIPTION OF THE AREA.

The area described in the present report is in the northwestern part of the state, as shown on the map of Wisconsin, fig. 1. Four of the counties border on the state of Minnesota on the west. It is approximately between the parallels 44° 30′ and 45° 45′ north latitude, and the meridians 91° and 93° west longitude, which is the same latitude as central Maine on the Atlantic coast, and northern Oregon on the Pacific, and the same longitude as central Louisiana, Arkansas, and Missouri in the Mississippi valley.

The area includes the counties of Eau Claire, Chippewa, Rusk, Barron, Dunn, Pepin, Pierce, St. Croix, and Polk. These nine counties contain 186 townships and have a total area of 6,705 square miles, approximately one-eighth of the state.

Slope and General Features. The area slopes down towards the southwest. The lowest land, 680 feet above sea level, is in the southwest corner of the area at the junction of the Chippewa and Mississippi rivers. The highest land is undetermined but is very probably the hard quartzite ridges of eastern Barron and western Rusk counties. Several of these ridges reach elevations of 1,500 to 1,600 feet above sea level, the lower land surrounding these highest ridges in the northern part of the area in general, having a varying altitude between 1,100 to 1,300 feet.

The western part of the area, Pierce and St. Croix counties, are mainly limestone uplands, in which the valleys are relatively

[redacted]

deep and narrow. A large part of Polk and Rusk counties is a nearly level plain, with broad shallow valleys.

FIG. 1.—Map showing the location of the North Western and North Central Wisconsin areas.

The principal topographic feature of the area is the relatively level or gently sloping surface of the land. Like other parts of the Mississippi valley it is an undulating plain into which valleys have been cut by the rivers and streams.

Upon the broad uplands of much of the area also are extensive deposits of glacial drift which in many places still retain the general forms left by the great ice sheets that have invaded this region. The beautiful lakes in the region are also intimately related in origin to the glacial deposits. Besides the glacial deposits there are extensive wind deposits of loess over large portions of the uplands of the area. In many of the valleys

are thick deposits of loose sand and gravel which assume the forms of terraces.

GEOLOGY.

The formations of the area may be grouped into two divisions and six sub-divisions, as follows:

Indurated Formations:

1. Crystalline rocks.
2. Sandstone.
3. Limestone.

Surface Formations:

4. Glacial drift.
5. Alluvial or river deposits.
6. Loess.

A generalized map showing the indurated or bed-rock formations is presented in Plate II. A cross section showing the relations of the formations is shown in figure 2.

1. Crystalline Rocks. This group, mainly of Pre-Cambrian age, includes several kinds of rock, such as granite, quartzite and trap rock. The granite rocks which include light colored schists, gneiss and granite and dark colored coarse and fine grained diorites, are found mainly along the Chippewa river and its tributaries above Eau Claire. Many wells reach the granitic rocks in northern Chippewa and in Rusk counties. The quartzite forms the high hills and ridges in eastern Barron and in western Rusk counties. Flambeau Ridge is also quartzite. The trap-rocks (Keweenawan) occur in the vicinity north of Osceola and at St. Croix Falls and extend in a belt farther northeast across the central part of Polk county, to Clam Falls.

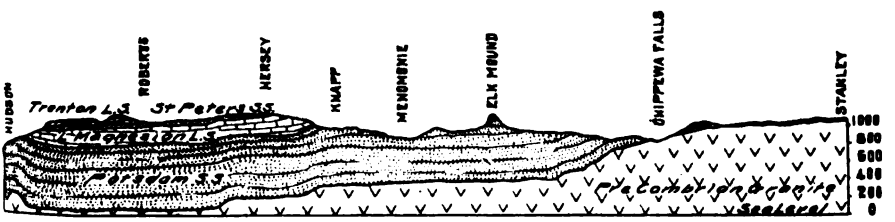

FIG. 2.—Section showing geological formations.

Origin of the Crystalline Rocks. Most of the crystalline rocks, such as the granite and trap rocks, are of igneous origin, and were brought to the surface from the interior in a heated molten

condition. The quartzite, however, was originally a sandstone, and was metamorphosed into quartzite by the great heat developed by the intrusive igneous rocks. None of the crystalline rocks contain fossils.

2. Sandstone. The Potsdam sandstone (Middle Cambrian) formation is the prevailing surface rock in Eau Claire, southern and western Chippewa, southern Barron, Dunn, and eastern Pepin counties. It lies beneath the drift in parts of Rusk, northern Barron and Polk, and is exposed along the bottoms and side of the valleys. The Potsdam sandstone lies in horizontal beds upon the crystalline formations, a fact to be noted in all cases where the two formations are exposed together or where wells penetrate both. The sandstone is quite generally a soft friable stone. In many places, the formation contains beds of shale rock, and green-sand. The fine sandstone weathers into a sandy soil but where shale and green-sand occur, loams are developed. Where the sandstone is overlain with glacial drift, the soil has the loamy character of the drift covering.

Origin of Sandstone. The sandstone is a form of sedimentary rock deposited in shallow water of the sea. Common fossils in the Potsdam sandstone are the shells or casts of trilobites, a kind of crustacea, and of small brachiopods, a kind of bivalve.

In Pierce and St. Croix counties, in the area of the limestone, is the thin formation of St. Peter sandstone (Ordovician). The St. Peter sandstone overlies the Lower Magnesian limestone and while it does not form many outcrops it has modified the soil conditions to a considerable extent in many places in these two counties.

3. Limestone. The limestone, mainly the Lower Magnesian formation (upper Cambrian), forms the main bed rock in western Dunn and western Pepin counties, and over the entire area of Pierce and St. Croix counties. The limestone also forms the summits of many of the uplands in eastern Pepin and southwestern Eau Claire. It extends as far north as southern Polk county where it is generally overlain, however, with thick drift, and is exposed only along the rivers.

In western Pierce and southwestern St. Croix counties are numerous high uplands and ridges capped with Trenton limestone (Ordovician). The soils developed on the limestones are generally loams and consist of a modification of local limestone

soil with the surface formations of glacial drift and loess that covers the general area of limestone in this district.

Origin of the limestone. The limestone is a sedimentary rock, mainly of organic origin, being formed generally from the accumulation of lime-bearing shells and skeletons of sea organisms, more or less broken up into fragments by waves of shallow water. Common fossils in the Lower Magnesian limestone are the articulated invertebrates, both the straight and curved forms, and also abundant corals. The Trenton limestone often contains abundant fossil shells or casts of bivalves, crustacea and coral.

4. Glacial Drift. The glacial drift (Pleistocene) consists of a mixture of ground-up rock containing varying proportions of clay, sand, gravel, and boulders Pl. III, fig. 1. The drift varies in thickness and was deposited upon the older bed rocks of the area by successive ice sheets that invaded this area and the adjacent portions of Wisconsin and northern United States. Between the periods of glacial invasions long interglacial periods occurred, and hence there is considerable difference in the age of the several drift sheets that are found in the area.

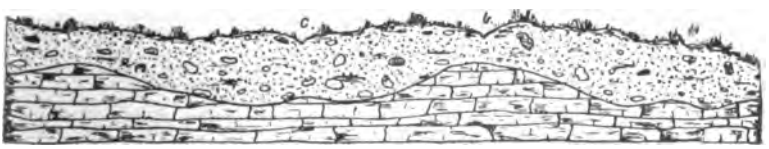

FIG. 3.—Diagrammatic section showing thick drift over rock.

There are some striking differences between the earlier and the later drift formations. Through the action of weathering processes, such as the work of frost, the seepage of groundwater, and the chemical alterations of rocks and minerals the earlier drifts have become more compact and consolidated and contain more clay and fewer boulders than the later drifts. Another important difference between the old and new drifts is in the surface or topographic features. The older deposits of drift have been subjected to a longer period of erosion than the later drift and for this reason the older drift has acquired long drainage slopes and prominent river valleys, while the newer drift subjected to a short period of erosion, is still characterized by belts of steep drift hills and ridges, bouldery "hogsback" ridges, swamps, and lakes. The soil condition of

the old and new drifts, therefore, are unlike in several important respects.

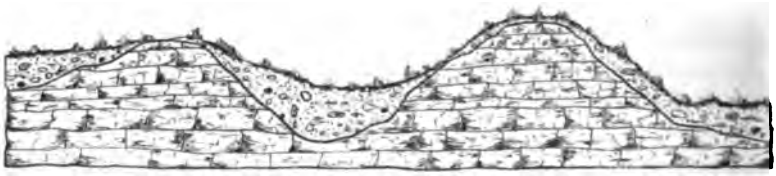

FIG. 4.—Diaggrammatic section showing thin drift over the underlying rock.

The old drift is abundant in southern Chippewa county and in a belt of considerable width extending from southern Barron county southwest through eastern St. Croix and over most of Pierce county. While the old drift also occurs over most of Dunn and Eau Claire counties and in western Chippewa and southeastern Barron counties it occurs only in relatively small quantity and is not important from the standpoint of the soils.

The area of the new drift is in the northeastern half of Chippewa county, the whole of Rusk, the eastern part and the northwestern part of Barron, the whole of Polk and the northwestern half of St. Croix. The new drift area is characterized by terminal moraines, lakes, and swamps.

5. Alluvial Deposits. The alluvial deposits made by the rivers of the area consist mainly of gravel and sand and form level tracts of variable width in the valleys. Some time during the past, between the periods of the formation of the earliest and the latest glacial deposits, there was a time of extensive valley filling in the area and adjacent parts of the state, presumably caused by a general depression of the land. The rivers and streams were unable to carry away the land wash brought down from the upland slopes and were forced to deposit large amounts of gravel and sand along their courses. In this manner, broad sand and gravelly plains were built up along the Mississippi, the Chippewa, the Red Cedar, the Eau Claire, and other rivers of the area. The alluvial plains cover large parts of Eau Claire, southern Chippewa, Barron, Dunn, and Pepin counties. Alluvial formations occur in the other counties also but are not extensive.

Alluvial Terraces. After filling its valley with waste for a time, a river may change its action and entrench its course in the built-up flood plain. The part of the plain remaining above the new valley floor is called a terrace, or alluvial terrace.

Fig. 1. TYPICAL SECTION OF GLACIAL SOIL.
Shows eighteen feet of glacial drift consisting of sand, clay and boulders, at Osceola, Polk County.

Fig. 2. TYPICAL SECTION OF LOESS SOIL.
Section shows ten feet of loess, characteristic of the lower slopes of valleys, near Menomonie, Dunn County.

The Chippewa valley below Chippewa Falls is characterized by a well defined system of five terraces which are especially well developed in the vicinity of Eau Claire. A cross section showing the terraces is illustrated in Figure 5. Well defined terraces are also developed along the Mississippi river and also along the St. Croix and Red Cedar.

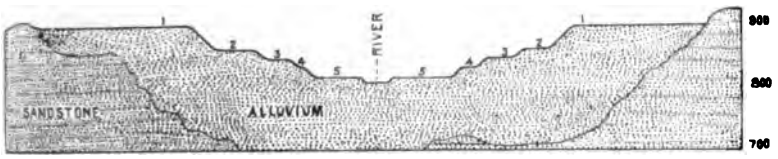

FIG. 5.—Section showing terraces in the Chippewa Valley below Eau Claire.

6. The Loess. The loess consists of fine loam or silt which overlies the bed rock and the glacial drift of considerable portions of the area. It is usually from one to five feet thick and is found mainly on the uplands and slopes and occasionally in the valley bottoms. A view of the loess is shown n Pl. III, fig. 2. The counties in which the loess is an abundant surface formation are Eau Claire, Chippewa, Dunn, Pierce, and Pepin. The loess is mainly restricted to the areas occupied by the older drift formations and to that part of the area in eastern Pepin and western Eau Claire which is entirely free from drift. The loess very probably mainly owes its origin to the action of wind in recent geologic time, probably during the time of one of the later glacial stages.

The loess is free from stone or any other rock material too large to be transported by wind action. It is essentially of uniform character and forms one of the most fertile soil types of the area.

GEOGRAPHY.

The various geographic forms of the land, the valleys, the hills and the plains are the results of the work of the rains and the rivers, the glaciers and the wind, acting throughout a long period of time. In some parts of this area the work of the glaciers and the wind is not important but in most parts of the area these influences were very important in shaping certain forms of the land. In all parts of the area, however, the work of the rain in its course down the land slopes, and of the rivers

and streams flowing through the valleys, were of great importance in shaping the land features.

Hills. The area contains but few hills that reach an elevation exceeding 200 or 300 feet above the adjacent valleys. The highest hill in the area is Flambeau Ridge in northern Chippewa county, which reaches 400 to 500 feet above the adjacent valley of the Chippewa and Flambeau rivers. Other notable high hills are the ridges of quartzite trending northeast and southwest in eastern Barron and western Rusk counties. In Polk county are ridges and broad uplands of trap rock trending in a northeast direction. Elk Mound is a prominent hill of sandstone capped with limestone in eastern Dunn county. Along the Lower Chippewa, the Red Cedar, the Mississippi and the St. Croix rivers there are steep mounds and valley slopes rising abruptly to heights of 200 to 500 feet above the adjacent rivers.

Origin of hills and ridges.—The hills and ridges of the area were carved into their present reliefs by the erosive work of the rains and the streams. Two types or ages of hills and ridges may be distinguished in the area: One type was formed at an early geologic period out of the crystalline rocks, and the other type was formed at a much later period out of the sandstone and limestone formations. Such ridges as Flambeau Ridge of northern Chippewa county and the high quartzite ridges of eastern Barron and western Rusk counties and the high ridges of Polk county were formed as hills before the age of the Potsdam sandstone. They were subsequently buried under the deposits of sandstone, and in the later period of denudation of the land were uncovered again by erosion. They are in reality fossil hills, like the Baraboo Ridges, and are the remnants of old Archean mountains, the oldest hills on the continent. The other type of hills consisting of sandstone or limestone, like Elk Mound, and like Mt. Tom and Mt. Simon at Eau Claire, and other mounds in the western part of the area, were formed during the present period of erosion, contemporaneous with the denudation of the old crystalline hills.

Terminal Moraine.—A prominent feature of the topography is the belt of boulder ridges and drift hills forming the terminal moraine of the latest ice sheet that invaded the region. This belt of terminal moraine consists of billowy hills associated with swamps and lakes, and has a usual width of 2 to 6 miles. These

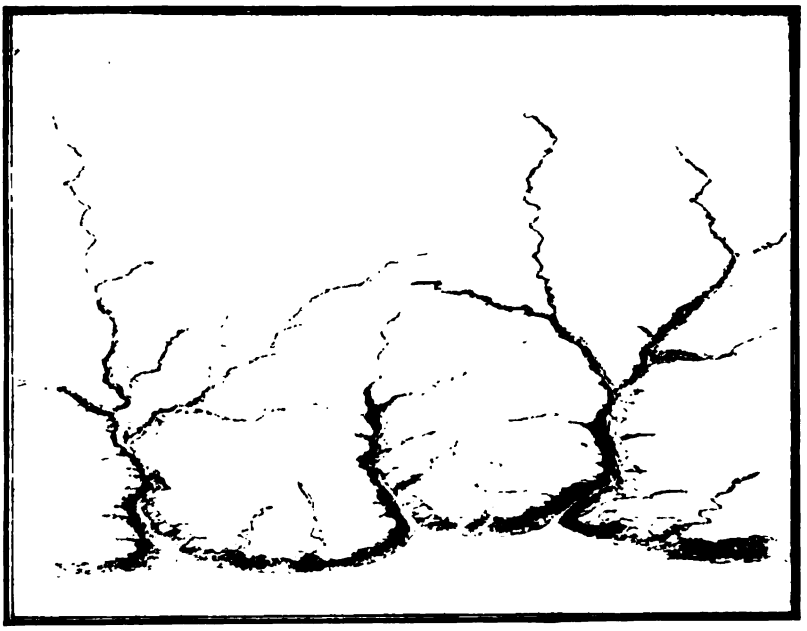

Fig. 1. YOUNG VALLEYS.

Fig. 2. SAME VALLEYS SHOWN IN FIG. 1, IN A LATER STAGE OF DEVELOPMENT.

undulating hills generally reach a height of 50 to 100 feet above the surrounding lower land.

The terminal moraine of the Chippewa valley ice lobe extends from the vicinity five or six miles north of Stanley westward to Jim Falls on the Chippewa river, then turns to the north and passes through the west central part of Chippewa county and along the border of Rusk and Barron counties, crossing the northeast part of Barron county in the region of Red Cedar lake. From the vicinity of Haugen there is another belt of moraine, formed by the St. Croix valley ice lobe, lying across the northwestern part of the area and extending through the vicinity of Cumberland, Turtle Lake, Clear Lake, New Richmond, Chapmans and Glover. The topography of terminal moraine is illustrated in Plate VIII.

Origin of the Terminal Moraines.—The terminal moraines are the thickened belts of drift accumulated at the margin of the ice sheets, where the ice margins remained essentially constant for a considerable time. A large amount of drift material gathered by the ice in the advance is dropped at the edge of the ice on account of the wastage of the ice by melting.

Rivers and Valleys.—The Chippewa river is the largest river, and, with its tributaries, drains about two-thirds of the area. Its principal tributaries flowing from the east are the Eau Claire, Yellow, Jump, Flambeau and Thornapple. On the west side of the Chippewa the main tributaries are the Eau Galle and Red Cedar. North of Chippewa Falls the Chippewa river has a broad shallow valley, but to the south the river has a deep valley bottom bounded on both sides by abrupt uplands rising from 100 to 200 feet or more above the sandy river bottoms. A series of terraces occur along the valley bottom from the vicinity of Chippewa Falls down to the Mississippi.

The Eau Claire river has a sandy valley bottom relatively narrow near its junction with the Chippewa but very wide in the eastern part of Eau Claire county. The Yellow river has a broad sandy plain below Cadott, but farther up stream the river winds among drift hills with no marked valley depression. The Jump and Flambeau rivers are not intrenched in prominent valleys but have their courses in broad drift-covered, slightly undulating plains.

The Red Cedar river drains about one-fourth of the area.

In its lower course from Cedar Falls to its mouth, the river flows in a narrow rocky gorge. The upper part of the valley is quite broad and in striking contrast with the lower narrow portion. It is very probable that the broad valley east of the river about Rusk prairie, was originally the main valley of the Red Cedar, and that the river below Cedar Falls is at present in a relatively new channel. The valley about Chetek, Cameron and Rice Lake is a broad plain from two to six miles wide.

The Eau Galle river in the vicinity of Woodville and further north has a broad valley, but south of this it has a relatively deep valley from 100 to 200 feet deep with precipitous banks on either side. At Spring Valley the valley bottom is narrow, generally less than one-half mile wide, but farther south it gradually widens, being about a mile wide below Eau Galle where it opens out into the valley of the Chippewa.

The Mississippi and the St. Croix rivers form the western boundary of the area. The Mississippi river has a prominent valley bounded by steep escarpments rising abruptly from 200 to 500 feet above the river. The principal tributaries flowing into the Mississippi are the Rush river, Isabel creek, Trimbelle river, and Big river. All these tributaries have deep prominent gorges in their lower courses. The valley of the Rush is prominent as far north as Martell.

The St. Croix river lies in a relatively deep valley throughout its course in this area. The valley is especially prominent and picturesque at St. Croix Falls and south as far as Stillwater. South of St. Croix Falls at the Delles of the St. Croix, the banks of the river rise abruptly to heights of 150 to 200 feet. From Stillwater to Prescott the river broadens out into Lake St. Croix.

The principal tributaries of the St. Croix in this area are the Kinnikinnic, Willow, and Apple rivers. The Kinnickinnic below River Falls has a deep and narrow valley with precipitous banks. The Willow below Burkhardt is prominent. The valley of the Apple is fairly prominent below Somerset, and especially prominent below Big Falls only a short distance from the St. Croix.

Origin of the Rivers and Valleys.—The valleys were carved out of the surface of the land by the erosion of the rivers and streams that flow through them. Rivers and valleys therefore

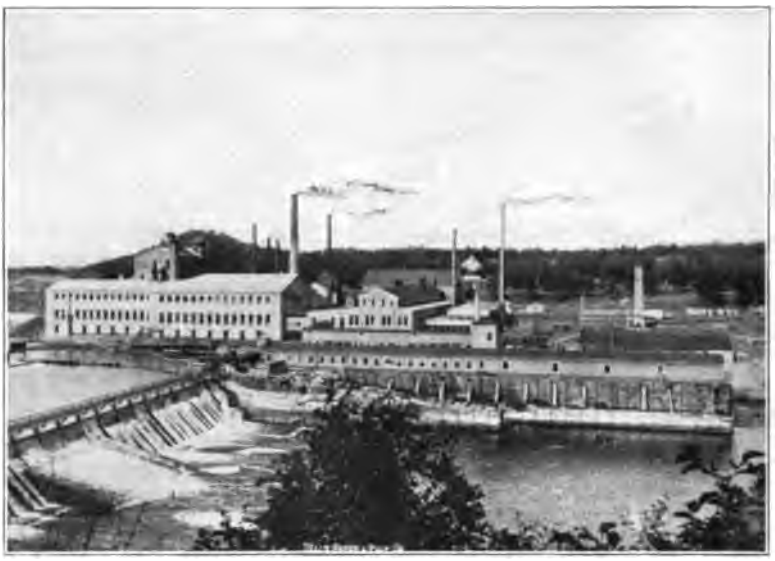

Fig. 1. DEVELOPED WATER POWER ON THE CHIPPEWA RIVER AT EAU CLAIRE.

Fig. 2. UNDEVELOPED WATER POWER ON THE CHIPPEWA RIVER AT BRUNETTE FALLS.

are so closely connected in life history that they can best be described together.

The rains that fall upon the land surface flows off the slope and tends to gather into rills and to wash-out gullies as illustrated upon every hillside after any considerable shower. The gullies grow into ravines, and the ravines grow into valleys by the simple work of running water. By constant erosion the valleys lengthen and broaden out and the inter-valley areas become narrower and narrower, as illustrated in the figures of Plate IV.

Rivers and streams work untiring throughout their courses. The more rivers are studied the more wonderful their place in nature is found to be. They wash along in every part of their course the waste of the land on the way to the sea.

Falls and Rapids.—Falls and rapids are common features of the rivers of this area. These are usually developed in the valleys where the streams cross from a more resistant rock to a less resistant one. In the course of time, however, the streams will succeed in cutting down these harder rocks of the rapids to grade with the stream above and below. Rapids and falls, therefore, belong to the youthful stage of a valley history rather than to that of old age. Waterfalls and rapids are an important natural resource of the area and many of them have already become sites for the development of valuable water power. The location of nearly all the large cities and villages of the area has been determined by the presence of rapids. The cities of Eau Claire, Chippewa Falls, Menomonie, Rice Lake, River Falls, New Richmond, Ladysmith, Barron, Cumberland, St. Croix Falls and many small villages are located on river rapids. Examples of river rapids and developed power on the Chippewa river are illustrated in Plate V.

Lakes.—The districts containing lakes and swamps lie in the northeastern and in the northwestern parts of the area, as may be seen on the map, Plate I. In the northwestern part of Chippewa and southwestern Rusk counties, the most prominent lakes are Long lake, Island lake, and Potatoe lake. In Barron county are Chetek, Prairie, Pokegema, Rice, Red Cedar, Bear, Beaver Dam, and Big Horse Shoe lakes. The most prominent lake in St. Croix county is Bass lake. In Polk county there

are many lakes, the largest being Cedar lake, Sucker lake, Round lake, Balsam lake, and Bone lake.

Lake Pepin, an enlargement of the Mississippi river and Lake St. Croix, a similar enlargement of the St. Croix river are prominent lakes on the western border of the area.

Origin of the Lakes.—The existence of any hollow which is capable of holding water may give rise to a lake and hence many of the sags and depressions in the terminal moraines are occupied by lakes and ponds. Many lakes in this area also are due to the depressions of drift in pre-existing valleys. Such elongated lakes as Red Cedar, Bear, Beaver Dam, Bone lake and Sucker lake were formed by the blocking of valleys by the drift.

Another type of lake is formed in the abandoned meanders of the large rivers, such as the Chippewa and St. Croix. Lake Hallie, north of Eau Claire, is an example of this type.

The life history of lakes is transitory as compared with that of rivers. The lakes of the area are comparatively recent in origin and do not date back beyond the formation of the last two drift sheets. The usually recognized processes operating to destroy lakes are three: the down-cutting of the outlet, thereby draining the lake; the filling of the lake by detritus eroded from the lake shore or brought in by streams; and the accumulation of organic matter, both vegetable and animal, such as peat and marl, formed in the lake itself.

Rock and Mineral Supplies.

The rock formations of the area furnish material for various useful purposes. The crystalline rocks, occurring as boulders in the glacial drift, or in the solid rock ledges are used to a variable extent as crushed stone for road material. The Potsdam sandstone furnishes good building stone in many localities. The important sandstone quarries at Colfax and Dunnville supply large quantities of good building stone. The limestone is quarried for building stone for local uses in Pierce, Pepin and St. Croix counties. The limestone in the vicinity of Spring Valley is used as a flux in the Spring Valley Iron Furnace. It was also formerly burned for lime at various lime kilns in one area but this industry has been largely discontinued.

Common brick clays occur abundantly throughout the area.

An important brick industry is carried on in Menomonie and Tramway in Dunn county. The manufacture of brick is carried on also at Chippewa Falls, Stanley, Ladysmith, Barron, St. Croix Falls, Amery, Barronett, Spring Valley, River Falls, Durand and Ellsworth. At present drain tile is not manufactured at any of these yards. Drain tile is made from the more plastic and finer-grained brick clays. Good drain tile could probably be made at several of the brick yards mentioned.

Good road material is abundantly supplied in the drift covered areas by the boulders and gravel in the drift. The trap rock ridges of Polk county, the granite ledges along the Chippewa river and tributaries in Eau Claire, Chippewa and Rusk counties are available sources for crushed rock for the construction of macadamized roads and streets. In the vicinity of Eau Claire the Potsdam shale is used quite extensively to improve the sandy roads.

Water Supplies.

The many streams and lakes of the area furnish an abundant supply of good water for stock. At most of the farm houses, however, wells are mainly relied upon to furnish water for domestic purposes.

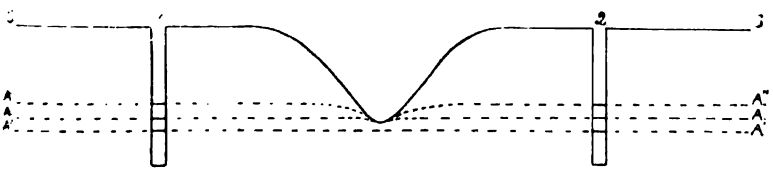

Fig. 6.—Diagram illustrating relations of groundwater to streams and wells. The dotted line AA represents the usual groundwater level which rises to A" A" in wet seasons and sinks to A' A' in dry seasons.

Well water is found at various depths below the surface, depending mainly upon the general topography, the distance above the permanent stream levels, and the character of the underlying rock formations. At certain depths below the surface all the pores and fissures in the rock are filled with ground water and it is into this water-filled portion of the ground that wells must be sunk in order to obtain an abundant and constant supply. The upper surface of the ground water, the ground water level, is usually very near the level of the permanently flowing streams and rivers of the area. The level of ground-

water is not exactly horizontal but is slightly undulating in general conformity with the topography of the land surface. The relation of the ground water level to streams and wells is shown in the diagram, fig. 5.

Some of the lake levels of the small lakes in northeastern St. Croix county, are somewhat unusual in being far above the general level of the groundwater. Wells in the immediate vicinity of these lakes go down 50 to 100 feet below the lakes to reach the ground water level and obtain a permanent water supply.

Changes in Groundwater Level. The level of groundwater rises and falls from season to season depending upon the seasonal rainfall. It also changes locally from year to year, due to amount of annual rainfall. The ground water level is also appreciably lowered where considerable pumpage or flowage from wells takes place.

Character of the Well Water. The well water within the area, is known in domestic economy as "soft water" and "hard water." The soft waters are located within the general area of the sandstone and crystalline rocks in the northeastern and eastern parts of the area and the hard waters are mainly confined to the area of the limestone in the western part. One of the softest waters in the United States is the famous Chippewa Spring water of Chippewa Falls. A well known mineral water, is used extensively for bottling purposes, at the Bethania Mineral Springs at Osceola. North of Osceola a few miles, is a flowing well, made in exploring for copper, which is unusually strongly mineralized.

It is possible therefore, to find waters within the area, containing but slight traces up to large amounts of mineral matter, though in general the well waters usually used for domestic purposes are only the ordinary phases of hard and soft waters. Much of the glacial drift of the northwestern part of the area in Polk and Barron counties contains much limestone material and hence the waters from these localities are also generally hard waters.

Wells in the Alluvial Sands and Gravels. Abundant well water is readily obtained in the sandy and gravelly stretches along the rivers and main streams of the area. Very generally the wells are sunk to the approximate level of the adjacent

rivers. Along the Chippewa river south of Chippewa Falls, the wells on the highest benches of the alluvial plains are from 50 to 100 feet deep. In the broad sandy plains of eastern Eau Claire county and in northern Chippewa, in Rusk, Barron, and Polk counties, wells are usually shallow, only from 10 to 30 feet deep. As a rule in order to secure good pure water the wells should obtain their supply more than 20 feet below the surface and where the groundwater stands less than 20 feet from the surface, drive wells or drilled wells should be made.

Wells in the Glacial Drift. Water is found at various depths in the sand and gravel of the glacial drift. The deepest wells in the drift, usually from 50 to 100 feet deep, are those in the hilly portions of the terminal moraines. On the more level areas of the drift the wells usually vary from 20 to 40 feet in depth. Where the drift overlies the crystalline rock, as in the northeast part of the area, abundant water is usually found within the drift, or at the contact with the underlying crystalline formations. Where the drift overlies limestone and sandstone however, the wells usually have to penetrate the latter to a variable depth to the general level of the underground water.

Wells in the Potsdam Sandstone. Wherever the sandstone has a thickness of 10 to 20 feet or more and the land is gently sloping, it usually furnishes an ample supply of water. The wells in the sandstone ridges and uplands usually have to reach down to the level of the surrounding low lands along the running streams to obtain a water supply.

Wells in the Limestone. The wells in the limestone rock are mainly confined to Pepin, Pierce and St. Croix counties. In Pepin and Pierce, while the wells penetrate limestone, the water supply is generally obtained from the underlying formation of Potsdam sandstone. In St. Croix, however, many wells obtain water from the Lower Magnesian limestone at depths of 50 to 150 feet below the surface. Many wells in Pierce county on the limestone uplands are from 150 to 300 feet deep and obtain water from the underlying Potsdam sandstone. In some places in St. Croix county where the St. Peter sandstone contains a thin bed of shale at its base, a water supply is obtained where the wells reach these shale beds but do not penetrate through.

Wells in The Crystalline Rocks. Wells that obtain their water supply from the crystalline rocks are mainly confined to northeastern Chippewa and Rusk counties and along the belt of trap rock in central Polk county. The wells in the trap rock in Polk are of varying degree of efficiency, and occasionally it is impossible to get a satisfactory supply from this formation. Where there is an overlying formation of drift or sandstone having a thickness of 10 to 20 feet which may serve as a catchment basin for water, a supply can be obtained by going down to the trap rock or a short distance into it.

The crystalline rocks in northern Chippewa and Rusk counties quite generally furnish a sufficient supply of water for domestic purposes. Where the overlying drift and sand is more than 15 or 20 feet thick, a supply can generally be obtained at the contact with the crystallines or within a few feet into the latter formation. Where the crystalline rock is massive and in solid formation, it is more difficult to obtain water than in the much fractured and fissured rock, for it is from the openings in the rocks that the water is obtained.

In drilling wells in the crystalline rocks, the heavier drills should be used, those having a combined weight of bit and stem of 1200 to 1400 pounds. The light weight drills usually make too slow progress. The possible clogging of water passages in drilling crystalline rock should be taken into account.

In the crystalline rocks most of the water is near the surface because of the larger proportion of rock opening near the surface, and hence, dug wells are often much more satisfactory than drilled wells. The dug wells being of larger diameter open up a larger number of veins and fissures and also have a larger storage capacity and on this account need not be so deep as the drilled wells.

Artesian Wells. Artesian flowing wells are obtained in the southwestern part of the area, on low ground along some of the rivers and streams. The sources of the flows are in the Potsdam sandstone and also in the alluvial formations in the valleys. The Artesian wells in Durand obtain their flows from depths of 200 to 500 feet, the water rising 25 to 35 feet above the level of the Chippewa river at Durand. The flowing wells that furnish running water for the Fish Hatchery at Hudson have their

source in the alluvial sand and gravel of the Willow river and are only from 10 to 15 feet deep and rise only a foot or so above the general level of standing water. There are some flowing wells also near Arkansaw and in the vicinity of Osceola.

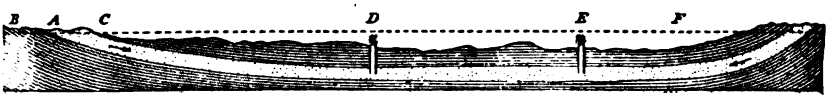

FIG. 7.—Section of an artesian basin. *A*, Porous stratum; *B*, *C*, impervious beds below and above *A*, acting as confining strata; *F*, height of water level in porous beds *A*, or, in other words, height in reservoir or fountain head; *D*, *E*, flowing wells springing from the porous water-filled bed *A*.

It is only on very low ground in Pepin, Pierce, St. Croix, and Polk counties that artesian flows are likely to be obtained. In the southeastern part of the area, artesian flows are not known at present, though they might be developed occassionally in small restricted areas in the glacial drift or in the alluvial deposits.

Origin of Flowing Wells. The water in wells that flow at the surface is under pressure. The essential condition for the existence of a flowing well is a relatively porous stratum lying between impervious strata, or below one; the porous stratum which transmits the water having an outcrop or catchment area at a higher elevation than the water bearing stratum at the well. In this manner the water in the porous stratum is held under pressure and when penetrated by a well the water tends to rise up to the level of the intake. There are many qualifying conditions that effect the quantity of the flow or the pressure. Artesian systems of flowing wells are lllustrated in figures 7 and 8.

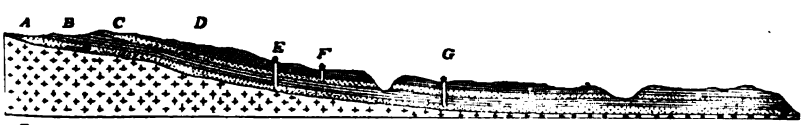

FIG. 8.—Section of an artesian slope. A and C are water-bearing beds; B and D are relatively impervious beds acting as confining strata; E, F and G are flowing wells springing from the water-bearing beds.

Springs. There are many large springs in the southwestern part of the area, along the lower Chippewa river, the St. Croix, and Mississippi, and the tributaries in Pierce county. The copious springs at St. Croix Falls along the St. Croix are a well known feature of that locality.

Origin of Springs. A "spring" is properly applied to the water emerging from the ground at a single point or within a small restricted area. Seepage springs are springs in which the water seeps out of sand or gravel. Such springs are usually marked by abundant vegetation, and their waters often carry a scum due to the decomposition of vegetable matter or the presence of iron. The scum is frequently mistaken for petroleum. Springs of this kind commonly occur along the sides or bottoms of valleys, as illustrated in figure 9.

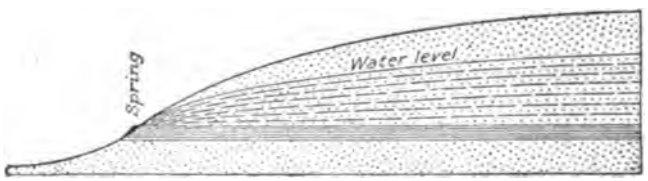

FIG. 9.—Spring fed from unconfined waters in porous sand.

Fissure springs are those that issue along bedding, cleavage, or fault planes. The waters are deeper seated and are almost never subjected to contamination. The accompanying diagram, fig. 10 illustrates a typical fissure spring. The springs at Ilwaco on the St. Croix river are of this type.

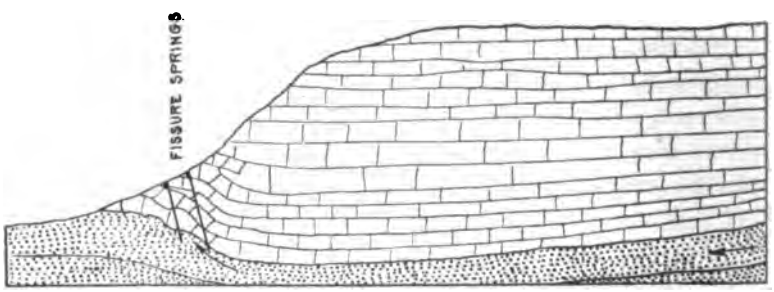

FIG. 10.—Fissure spring. Waters spring from the underlying porous sandstone up through fissures in the limestone.

The Pollution of Well and Spring Water. Farms, which are generally remote from towns and cities or other areas of congested population are especially favorably situated for obtaining pure and wholesome water. As a matter of fact, however, polluted water is exceedingly common on the farms, and typhoid fever, generally contracted from drinking water, is usually more prevalent in country districts than in cities.

Many of the failures to protect water supplies used for drinking are due to a lack of knowledge of the manner in which waters circulate through the ground and of the ways in which the ground water may become polluted. The diagram, fig. 11 il-

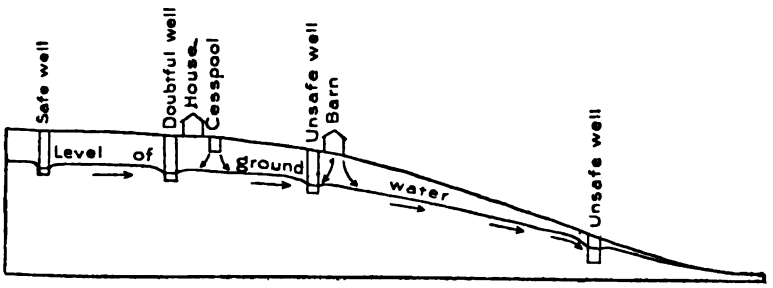

FIG. 11.—Diagram showing location of safe and unsafe wells and their relation to farm buildings.

lustrates the location of safe and unsafe wells, and the general relation of these to the location of farm buildings and to the ground water level.

Springs may also be contaminated, especially the seepage springs, if proper care is not taken in the location of buildings near the spring. Open or dug wells may be polluted by material seeping through the ground and curbing or entering from the top of the well.

The distance from a source of pollution, such as cesspools and barnyards, at which a surface or open well may be sunk with a fair degree of safety varies with the formation but generally should never be less than 100 feet and often should be at least 200 feet. The more open and porous the soil and the more rapid the movement of the ground water, the greater is the safety distance required. Well waters that become muddy after rain storms indicate surface contamination and should be avoided

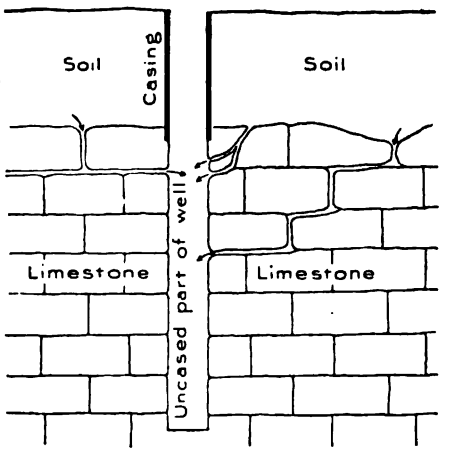

FIG. 12. Diagram showing danger of pollution where casing is carried only to rock.

if possible. Wells should be protected from surface water by properly constructed curbing, stock should be kept away from the well, and protection from pump drippings, from small animals, and dust should be ensured, as they are all possible sources of pollution.

The water of deep wells are usually safe and hence many people go to the expense of drilling for deep well water. Deep wells, may however become polluted by the entrance of surface waters (See fig. 12) unless the casing is carried into the well a sufficient depth to shut off all surface water entering through fissures.

Cisterns, which are especially valuable in supplying soft rain water or in furnishing supplementary supplies from wells, if properly constructed are safe sources of water supply. The disadvantage of cisterns is the liability of contamination by dust from the roof, and the liability to crack and admit shallow and possibly polluted waters.

WATER POWERS.

The water powers are a valuable natural resource of the area. A general survey of the water powers of the state has been made by L. S. Smith.* Much less than one-half of the available water power in the area is now developed. On the Chippewa river extensive power is developed at Eau Claire and Chippewa Falls, and on the Flambeau at Ladysmith. There are very many power sites still undeveloped on the Chippewa and Flambeau, among which may be mentioned the important sites at Jim Falls, Brunett Falls, and Holcombe on the Chippewa, and Burnt Island, Big Falls, and Cedar Rapids, on the Flambeau.

Water powers have been developed on the Red Cedar at Menomonie and Chetek, and on the tributaries of the Red Cedar at Rice Lake and Barron. The St. Croix river has many power sites in its upper course. At St. Croix Falls, is a 50 foot dam, having an estimated development of 27,000 H. P. at present only partially equipped, the power being conducted electrically to Minneapolis and St. Paul. There are no powers developed above St. Croix Falls but important sites are located at Nevers

* Bulletin No. 20, Wis. Geol. & Nat. Hist. Survey, Madison, Wis.

dam, at Kettle River rapids and farther north. Powers are developed on the Kinnickinnic river at River Falls, on the Willow at Burkhardt and New Richmond, and on the Apple at Apple River Falls, Somerset, and Huntington, the power developed on the Apple river, being conducted to Stillwater and Minneapolis.

ALTITUDES OF NORTHWESTERN WISCONSIN.

Elevations above sea level, of many of the railroad stations within the area, some of which are also indicated on the soil map, are shown in the following table:

TABLE I. *Altitudes of railroad stations.*

Station.	Altitude.	Station.	Altitude.
Amery	1,070	Hammond	1,104
Augusta	972	Hersey	1,201
Baldwin	1,136	Holcombe	1,045
Barron	1,111	Hudson	609
Bloomer	1,012	Knapp	928
Boyd	1,105	Ladysmith (on river above dam)	1,110
Bruce	1,098	Luck	1,207
Burkhardt	927	Maiden Rock	686
Cadott	977	Menomonie, C. St. P. M. & O.	788
Cameron	1,098	Menomonie Junction	884
Chetek	1,053	New Auburn	1,109
Chippewa Falls, C. St. P. M. & O.	866	New Richmond, W. C. R. R.	986
Chippewa Falls, W. C. R. R.	831	Osceola	809
Clear Lake	1,198	Pepin	688
Colfax	947	Prairie Farm	
Cumberland	1,241	Prescott	706
Dallas	1,052	Rice Lake	1,148
Durand	725	Ridgeland	1,083
Eau Claire, C. M. & St. P.	788	River Falls	886
Eau Claire, C. St. P. M. & O.	841	Roberts	1,039
Elk Mound	931	St. Croix Falls	920
Ellsworth	1,068	Spring Valley	922
Fairchild	1,018	Stanley	1,077
Fall Creek	939	Stockholm	692
Frederick	1,204	Turtle Lake	1,258
Glenwood	1,026	Woodville	1,152

TABLE II—*Altitudes of points on the important rivers.*

Station.	Altitude.	Station.	Altitude.
Chippewa River.		*Red Cedar.*	
Reeds Landing—High water.	680	Mouth of River....	705
Reeds Landing—Low water..	664	Dunnville.....	723
Eau Claire River, mouth.....	770	Irving.....	766
Chippewa Falls, foot of dam.	806	Menomonie, foot of dam.....	788
Yellow River, mouth.....	852	Cedar Rapids, foot.....	823
Jim Falls, foot.....	901	Hay River, mouth.....	859
Brunett Falls, foot.....	967	Colfax.....	895
Holcomb Rapids, foot.....	1,004	Cameron, (2 miles west).....	1,068
Flambeau River, mouth.....	1,050	Rice Lake (R.R.crossing)....	1,116
Bruce, Sec. 28.....	1,064	Cedar Lake, dam.....	1,191
Murray, N. E. Sec. 23.....	1,112		
Flambeau River.		*St. Croix River.*	
Ducommon Rapids.....	1,070	Prescott, mouth of river..... Low water	667
Ladysmith, below dam.....	1,099	Kinnikinnic River, mouth....	668
Little Falls Rapids.....	1,137	Apple River, mouth.....	672
Big Falls, foot.....	1,177	Osceola.....	683
Big Falls, head.....	1,209	St. Croix Falls (head of navigation.....	687
Rock Island rapids.....	1,233	St. Croix Falls (crest of dam)	750

CHAPTER II.

CLIMATE.

The climate of the area is not influenced by the Great Lakes but is influenced in a general way by its location with respect to the average track of the storms that move eastward, along the Canadian border, and those that move up the Mississippi valley from the southwest. As in other parts of the northern Mississippi Valley, extremes of temperature prevail, the summers being warm with abundant precipitation, and the winters cold and relatively dry.

Temperature. The climatic elements of greatest importance to agriculture are temperature and precipitation. The temperature conditions of the area, are shown in the two tables, Table III and IV. The period covered is from 15 to 21 years, the period ranging from 1890 to 1909, the data being compiled from a recent sectional report of the U. S. Weather Bureau of northwestern Wisconsin. There are at present nine Weather Bureau stations within and near the area, but of these five have records of observations for only a relatively short period, of three to five years. The stations at present in the area or near the area, are located at Barron, Downing, Grantsburg, New Richmond, Osceola, Stanley, Weyerhauser, Eau Claire, Ellsworth and Red Wing, Minn. In compiling the temperature data, only the stations at Barron, Osceola, Downing, Eau Claire and Grantsburg and Red Wing, Minn. are considered. Grantsburg, located in Burnett county, is but a short distance north of Polk county.

Table III shows the mean temperature conditions for the growing season of the year, from April to September. The mean or average temperature for each of the six stations for each month is given, and also the highest, and the lowest temperatures for each month. The mean temperature is the most important

datum to consider in agriculture, as the highest and lowest temperatures represent only the rare and extreme conditions.

By comparing the data for the several stations, it will be observed that the mean temperatures are almost identical at all the stations for the summer months, and yet there is a slight and persistent difference between them which is worthy of note. The temperature of Barron is about one to two degrees colder than that of Osceola and Grantsburg, and about two to four degrees colder than that of Eau Claire.

The table indicates that the summer isothermal lines or lines of equal temperature do not run east and west across the area, but run northwest and southeast. The summer temperatures of Eau Claire Dunn, and St. Croix counties are about the same. In the same way the summer temperatures of Chippewa and Polk would be the same. Rusk county is the coldest in the summer, and Pierce and Pepin counties the warmest as indicated by the records at Red Wing.

The Table IV showing the temperature for the non-growing season indicates that the temperature of Barron and the northeastern part of the area is slightly colder in winter than the western part of the area at Grantsburg and Osceola, as well as colder than the southern part of the area at Eau Claire. At all the stations there are much greater extremes in temperature in winter than in summer.

While the mean temperatures are the most important data in the tables, extremes of temperature are also of interest. The unusually low temperatures recorded in the area have reached 40° to 48° below zero, and unusually high temperatures have reached 100° to 105° above zero. There are generally from 5 to 10 days in winter when temperatures below 20° below zero may be expected, and from 5 to 10 days in summer when temperatures above 90° may occur.

TABLE III.—*Temperature of the growing season* (Fahrenheit).

STATION.	Elevation.	Length of record, years.	APRIL.			MAY.			JUNE.			JULY.			AUGUST.			SEPTEMBER.		
			Mean.	Highest.	Lowest.	Mean.	Highest.	Lowest.	Mean.	Highest.	Lowest.	Mean.	Highest.	Lowest.	Mean.	Highest.	Lowest.	Mean.	Highest.	Lowest.
Barron	1,115	18	42.2	88	10	52.9	94	18	63.4	97	25	68.2	103	40	64.9	98	34	58.5	99	22
Grantsburg	1,095	18	43.1	83	—7	54.6	93	15	64.8	98	23	69.1	105	39	66.4	98	33	58.6	96	16
Osceola	806	19	43.4	87	—4	54.6	93	16	64.7	99	25	69.1	105	34	67.0	104	30	59.9	99	20
Downing	983	15	43.2	84	4	54.7	98	17	64.4	100	28	67.9	103	35	66.7	100	32	58.6	97	12
Eau Claire	800	19	45.6	88	11	57.0	94	20	66 8	97	25	70.7	103	41	69.2	98	36	61.1	99	20
Red Wing, Minn	708	21	45.7	89	16	56.0	92	25	67.9	99	38	72.0	106	46	68.6	95	45	61.1	95	33

TABLE IV.—*Temperature of the non-growing season* (Fahrenheit).

STATION.	Elevation.	Length of record, years.	OCTOBER.			NOVEMBER.			DECEMBER.			JANUARY.			FEBRUARY.			MARCH.		
			Mean.	Highest.	Lowest.	Mean.	Highest.	Lowest.	Mean.	Highest.	Lowest.	Mean.	Highest.	Lowest.	Mean.	Highest.	Lowest.	Mean.	Highest.	Lowest.
Barron	1,115	18	45.7	86	10	29.5	72	—15	16 3	54	—28	10.3	54	—40	11.4	59	—40	25.5	75	—18
Grantsburg	1,095	18	46.8	84	7	30.8	75	—32	16.7	58	—39	10.9	52	—43	11.8	52	—45	26.2	73	—27
Osceola	806	19	46.8	86	3	29.7	70	—34	16.3	52	—40	10.0	67	—46	11.6	59	—47	26.6	73	—27
Downing	985	15	46.7	85	9	30.3	75	—24	16.7	53	—33	11.1	50	—44	12.3	62	—48	27.4	77	—20
Eau Claire	800	19	48.6	86	10	32.1	72	—15	18.7	54	—28	13.1	54	—34	14.3	59	—40	28.7	75	—18
Red Wing, Minn	708	21	48.7	80	18	33.3	78	— 9	20.1	50	—25	11.2	45	—31	15.1	50	—30	27.4	64	— 7

Precipitation. The precipitation,* which includes the snowfall as well as the rainfall, at the stations, Grantsburg, Osceola, Downing, Barron, Red Wing, and Eau Claire, is shown in the following tables:

TABLE V.—*Grantsburg, Burnett County, Wis.*

(Elevation, 1,095 feet.)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1889.....	....	....	....	2.55	3.4	1.96	4.00	....	4.01	T.	0.55	1.95	....
1890.....	1.20	....	2.25	....	"	10.76	6.17	7.51	2.50	1.55	0.71	....	....
1891.....	....	...	....	....	....	....	....	....	....	....	....	....	....
1892.....	....	....	....	....	....	....	....	....	....	....	1.10	0.80	....
1893.....	1.40	2.35	0.90	3.35	2.45	2.20	1.21	2.03	1.40	2.80	0.90	2.20	22.99
1894.....	1.40	0.20	2.40	5.15	7.41	1.41	0.55	0.72	1.80	3.72	1.80	1.37	27.93
1895.....	0.99	0.40	0.40	1.76	4.61	5.09	4.36	2.50	4.70	0.04	0.65	0.50	26.00
1896.....	1.15	0.50	2.57	7.10	5.91	3.47	1.30	1.53	2.63	4.22	4.75	1.35	36.48
1897.....	1.35	1.28	2.70	0.75	2.00	7.93	9.67	2.00	3.65	1.70	1.04	0.35	34.42
1898.....	0.39	0.88	2.12	1.64	4.85	6.00	1.59	2.67	1.90	5.70	1.80	T.	29.14
1899.....	0.77	1.57	2.56	2.50	5.97	2.30	2.08	4.89	1.63	4.63	0.67	1.93	31.50
1900.....	0.77	1.42	0.67	1.19	1.31	1.35	8.77	9.43	4.60	4.43	1.05	0.75	35.74
1901.....	0.50	0.65	3.98	1.65	1.13	5.26	3.49	2.13	4.25	1.68	0.88	1.02	26.62
1902.....	0.85	0.05	0.75	1.99	2.85	2.98	5.31	1.36	3.55	1.82	3.05	2.68	27.24
1903.....	0.82	1.90	2.17	4.25	6.55	1.12	9.37	5.70	10.02	3.14	0.60	1.50	47.23
1904.....	0.70	1.55	0.65	1.25	3.08	5.33	4.76	3.68	7.23	5.04	T.	1.50	34.77
1905.....	1.45	0.55	1.20	1.40	3.19	9.81	5.53	5.18	7.73	3.20	2.48	T.	41.72
1906	3.05	0.80	1.10	3.56	4.95	7.08	2.38	4.08	2.61	2.41	1.93	1.60	35.55
1907.....	1.80	0.90	2.30	0.85	2.15	7.11	4.35	2.44	9.38	0.40	1.00	0.50	33.18
1908.....	0.55	1.66	2.35	5.13	3.22	8.38	3.05	0.94	1.90	2.38	0.42	0.90	35.88
1909.....	0.90	2.15	0.45	4.02	3.50	1.57	5.75	3.28	3.93	3.03	3.50	2.50	34.58
Means..	1.11	1.11	1.75	2.78	4.11	4.80	4.40	3.45	4.18	2.70	1.44	1.23	33.06

Osceola, Polk County, Wis.

(Elevation 805 feet.)

1891.....	0.90	1.80	2.30	2.05	1.95	4.52	2.38	1.02	1.52	1.63	1.22	3.93	25.25
1892.....	0.03	1.47	1.13	1.32	8.10	8.14	6.22	4.64	1.34	0.62	0.49	0.63	34.13
1893.....	1.48	2.45	2.91	3.62	2.58	2.08	3.17	2.18	2.04	3.42	0.79	1.97	28.67
1894.....	1.07	0.15	2.80	4.74	9.95	2.40	0.44	0.65	1.85	4.09	0.13	1.60	30.47
1895.....	0.86	0.24	0.55	1.95	4.67	4.31	5.35	1.83	5.72	0.22	1.14	0.16	27.00
1896.....	0.71	0.10	2.34	5.67	4.80	6.63	1.83	4.38	2.77	3.54	3.20	0.79	36.82
1897.....	2.50	0.73	2.09	1.34	1.60	7.30	4.94	1.35	3.76	2.11	1.32	0.11	29.15
1898.....	0.03	1.13	4.43	1.63	6.60	4.92	1.32	4.24	0.87	5.67	1.09	0.07	32.60
1899.....	0.90	1.30	2.19	2.86	3.41	6.85	1.66	4.87	1.06	3.72	1.02	1.54	31.38
1900.....	0.35	0.92	0.70	1.95	0.36	0.90	9.76	7.96	8.14	6.08	0.71	0.67	38.50
1901.....	0.38	0.68	3.24	1.51	1.74	6.40	3.79	2.35	5.20	1.71	1.87	2.28	31.15
1902.....	0.76	1.42	0.80	1.95	2.54	3.02	3.98	3.60	3.99	1.23	2.55	2.11	27.85
1903.....	0.67	0.44	2.09	2.92	7.31	2.26	9.58	4.42	8.76	4.14	0.20	0.83	43.62
1904.....	0.70	0.88	1.37	1.52	5.21	5.64	5.05	3.54	5.66	5.32	T.	0.50	35.39
1905	0.35	0.78	0.73	0.62	2.77	6.27	2.05	5.35	6.01	2.62	1.80	0.20	30.15
1906.....	4.50	0.18	3.50	1.55	6.61	4.07	5.02	2.56	3.75	3.20	1.77	1.97	38.69
1907.....	1.39	0.53	0.70	1.05	0.06	3.35	4.51	2.98	7.33	1.45	1.12	0.20	25.27
1908.....	0.55	0.85	1.45	3.61	8.23	5.50	3.05	0.79	3.32	2.43	0.98	0.70	31.46
1909.....	0.86	1.41	0.85	2.50	2.05	5.68	3.53	3.66	3.80	2.20	4.45	1.92	32.91
Means..	1.00	0.92	1.90	2.33	4.27	4.75	4.12	3.28	4.05	2.95	1.39	1.17	32.13

* From Weather Bureau Report, Section 58, Northwestern Wisconsin.

Downing, Dunn County, Wis.

(Elevation, 963 feet.)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1891.....	2.05	2.63	3.12	3.37	2.14	4.30	2.44	3.85	1.41	4.16	0.52	5.33	35.32
1892.....	0.47	1.90	2.09	2.13	7.46	5.83	8.31	2.91	2.90	2.60	0.76	1.09	38.35
1893.....	1.43	3.53	2.81	6.17	2.55	1.54	2.81	2.33	2.59	2.93	0.77	4.01	33.47
1894.....	1.25	0.32	3.02	5.65	10.56	1.90	0.42	0.50	2.93	4.33	1.93	1.68	34.49
1895.....	1.23	0.55	....	....	....	....	....	....	....	....	....	....	.....
1896.....	....	....	....	....	....	....	....	....	....	....	....	....	.....
1897.....	....	....	....	....	....	....	....	....	....	....	....	....	.....
1898.....	0.25	1.04	0.87	1.23	2.67	4.86	2.11	3.55	0.89	4.45	1.04	T.	22.76
1899.....	0.65	0.60	1.10	1.60	5.87	8.37	1.64	4.91	3.42	4.45	0.80	1.90	35.31
1900.....	0.31	0.51	1.10	2.00	0.04	2.46	10.55	4 34	9.46	7.48	0.37	0.95	39.55
1901.....	....	....	....	2.15	....	....	....	1.31	5.20	1.39	....	....	.....
1902.....	0.60	0.90	0.30	2.15	3 80	3.00	3.73	2.00	2.45	1.65	3.80	3.61	27.99
1903.....	0.30	0.05	2.06	3.55	7.14	1.02	8.78	5.01	7.37	2.45	0 52	0.80	39.65
1904.....	1.00	0.65	2.10	2.00	4.72	4.92	5 60	4.90	4.20	7.44	0.10	0.90	38.53
1905.....	1.60	1.00	1.01	T.	5.90	7.05	2.65	7.40	2.30	3.15	1.06	0.50	33.62
1906.....	3.00	T.	1.20	2.25	8.44	4.45	1.95	5.63	4.91	3.51	1.68	1.80	38.82
1907.....	3.14	1.60	2.21	1.20	1.70	6.24	3.30	4.71	5.06	1.10	1.00	0.30	31.62
1908.....	0.91	1.80	1.50	5.45	2.75	9.32	1.60	1.50	1.20	1.03	1.08	1.20	29.34
1909.....	0.60	2.80	0.10	2.81	2.56	4.77	4.96	3.50	4.29	2.94	4.56	1.15	35.34
Means..	1.17	1.24	1.66	2.74	4.55	4.71	4.06	3.65	3.77	3.44	1.33	1.67	33.99

NOTE—Observations at Menomonie from January, 1891, to February, 1895; at Knapp from January, 1898, to June, 1902; at Downing from July, 1902, to December, 1909.

Barron, Barron County, Wis.

(Elevation, 1,115 feet.)

1891.....	....	....	....	....	....	2.68	1.86	1.42	1.46	1.90	0.70	4.52	.....
1892.....	0.26	1.73	0.98	2.29	7.03	7.44	4.61	3.94	1.77	1.80	1.04	0.71	33.60
1893.....	1.23	2.91	1.75	4.91	3.85	1.25	3.28	3.66	2.85	3.40	....	2.05	.....
1894.....	1.69	0.45	2.44	4.64	8.94	2.01	2.40	1.30	1.85	4.73	1.40	1.24	33.08
1895.....	0.83	0.60	0.48	1.68	3.63	4.87	4.93	1.78	3.90	0.26	0.80	1.66	25.42
1896.....	1.63	....	....	....	....	....	....	....	....	....	....	....	.....
1897.....	2.03	1.75	2.60	1.86	2.17	6.23	5.54	1.25	2.93	1.85	0.29	0.30	28.80
1898.....	0.25	1.83	1.80	1.02	4.40	2.27	1.90	2.51	0.98	4.64	1.00	T.	22.60
1899.....	0.45	1.16	3.30	1.73	3.15	7.00	2.00	5.87	0.65	4.26	0.95	2.02	32.54
1900.....	1 16	....	1.19	1.11	1.71	2.20	7.70	7.64	....	5.40	1.00	1.05	.....
1901.....	0.49	0.50	3.50	2.22	1.82	5.23	5.10	1.70	6.55	1.28	1.50	0.40	30.29
1902.....	1.50	0.26	0 86	2.06	3.63	4.39	3.65	1.09	2 39	0.68	4.30	1.37	26.18
1903.....	0.59	0.40	2.52	2.44	5.86	3.04	6.55	4.75	5.95	3.20	0.50	0.54	36.34
1904.....	1.25	1.40	1.14	2.20	6.55	8.45	6.15	5.51	6.76	5.61	T.	0 90	45.92
1905.....	1.50	0.50	0.47	1.00	4.50	13.70	3.50	8.50	3.70	2.40	2.70	T.	42.47
1906.....	3.20	0.40	1.00	2.58	7.45	3.84	2.40	2.92	2.08	1.20	0.43	1.00	28.50
1907.....	1.30	1.05	1.08	0.70	1.83	3.39	2.75	2.50	3.75	....	....	....	.....
1908.....	0.50	1.00	1.75	4.05	3.85	5.64	2.56	1.61	1.46	3.08	0.95	0.87	27.32
1909.....	0.35	1.35	0.80	3.61	2.60	2.58	2.96	4.08	4.27	2.54	4.48	1.24	30.84
Means..	1.12	1.08	1 63	2.36	4.29	4.79	3.88	3.45	3.14	2.84	1.38	1.17	31.13

Red Wing, Goodhue County, Minn.

(Elevation, 708 feet.)

Year.	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1885.....	.....	.....	0.54	3.09	1.89	4.62	5.99	2.70	4.43	1.62	0 44	0.81	.....
1886.....	5.25	0.65	1.36	4.68	1.45	3.23	1.50	4.51	4.99	2.58	2.29	1.18	33.67
1887.....	1.22	1.71	0.43	2.52	0.99	5.24	3.58	6.70	5.04	1.58	0.73	3.67	33.41
1888.....	1.45	0.91	3.35	4.92	7.53	3.01	3.30	3.34	1.32	1.63	0.24	0.98	31 [illegible]
1889.....	0.90	0.54	0.51	1.35	1.85	3.01	2.23	3.98	1.45	0.02	1.32	1.94	18.[illegible]
1890.....	1.36	0.53	0.98	1.87	4.55	8.03	1.80	3.96	3.15	3.38	0.72	0.15	30.48
1891.....	2.06	1.66	2.04	2.25	1.46	6.36	2.77	3.13	1.23	1 64	0.86	4.60	30.06
1892.....	0.17	1.90	0.87	1.09	6.06	7.74	7.17	1.80	3.38	1.18	0.40	0.66	30.42
1893.....	0.92	2.64	2.31	4.14	2.17	2.28	2.63	2.18	2.50	1.60	0.45	3.15	27.17
1894.....	0.90	0.35	1.10	3.30	2.71	2.61	0.10	1.45	2.54	5.12	0.40	0.95	21.53
1895.....	1.30	0.80	0.20	1.75	4.25	3.72	3.60	1.84	3.92	0.18	1.62	0.60	23.78
1896.....	0.97	0.20	0.20	4.56	4.10	2.98	1.31	1.55	2.79	2.73	3.10	0.95	25.44
1897.....	2.00	0.95	2.50	1.14	1.54	4.29	4.51	3.29	5.09	4.51	1.78	0.30	31.90
1898.....	0.32	1.50	3.22	1.38	3.08	2.07	3.01	3.80	0.48	5.25	2.76	0.00	26.87
1899.....	2.25	4.39	1.95	0.71	4.16	6.60	1.93	4.50	1.50	4.20	0.88	1.12	34.19
1900.....	0.79	1.21	1.09	1.83	0.26	1.57	4.43	3.56	6.70	3.21	1.33	0.75	26.73
1901.....	1.00	0.89	1.79	0.85	1.12	5 42	1 94	3.74	7.28	1.56	0.62	0.61	26.62
1902.....	0.46	0.63	0.90	2.36	6.75	2.29	8.72	4.36	4.01	2.62	4.02	1.56	38 74
1903.....	0.22	0.59	0.73	1.70	8.44	0.41	3.38	4.40	11.74	1.80	0.22	0.53	34.16
1904.....	0.31	0.63	1.09	0.88	3.29	5.04	4.56	3.52	4.57	6.30	0.00	1.32	31.51
1905.....	0.81	1.03	1.74	0.23	5.46	7.40	3.64	8.71	1.94	3.08	2.24	0.30	36.58
1906.....	1.86	0.25	2.22	2.10	7.41	3.15	3.60	4.30	2.16	2.44	2.54	1.20	33.63
1907.....	1.30	1.10	0.61	1.66	0.81	4.05	3.26	7.57	6.54	0.84	0.96	0.48	29.18
1908.....	0.26	0.98	1.68	4 10	6.08	9.10	3.60	0.76	2.06	3.68	0.82	0.80	33.92
1900.....	1.30	1.34	0.77	2.54	3.34	4.40	1.86	1.78	7.38	1.98	5.50	1.44	33.63
Means..	1.22	1.14	1.38	2.28	3.63	4.34	3.37	3.65	3.94	2.59	1.45	1.20	30.19

NOTE—From November, 1896, to December, 1909, inclusive, except January and February, 1908, the records are from the river observing station at Red Wing.

Eau Claire, Eau Claire County, Wis.

(Elevation, 800 feet.)

1891.....	.....	2.95	1.85	1.70	2.00	5.40	2.20	1.70	1.07	3.10	0.70	4.65	.....
1892.....	0.30	1.60	1.00	2.40	6.15	9.10	.....	.....	2.90	1.70	0.75	1.00	.....
1893.....	1.31	2.70	1.90	5.90	4.87	0.66	2.73	1.77	2.21	3.26	1.90	5.10	33.71
1894.....	1.30	0.90	2.03	2.92	6.62	.....	.....	.....	.....	2.90	1.23	1.09	.....
1895.....	0.98	0.44	0.22	1.67	1.17	5.60	4.13	1.28	4.06	0.56	1.83	0.90	22.84
1896.....	1.40	0.40	0.60	6.35	4.50	6.25	2.67	3.00	3.03	3.00	3.70	0.50	35.40
1897.....	2.00	2.75	4.10	1.16	3.65	5.05	3.26	3.20	2.10	2.49	0.92	0.72	31.40
1898.....	0.32	2.26	2.85	2.22	1.96	1.50	1.27	0.23	0.77	5.13	1.79	0.27	20 57
1899.....	0.98	1.47	2.90	1.58	8.47	7.02	1.62	7.67	3.23	3.61	0.67	2.20	41.42
1900.....	1.00	1.49	1.23	2.95	0.75	1.86	8.88	3.37	8.73	9.41	1.32	1.00	41.99
1901.....	0.56	0.63	3.58	1.45	2.26	6.47	4.01	2.06	5.71	4 64	0.54	0.55	32.46
1902.....	0.77	0.88	1.51	3.49	5.27	2.27	5.91	3.25	2.21	2.58	4.28	3.05	35.47
1903.....	0.32	0.87	2.10	3.72	7.03	2.44	8.78	5.09	9.12	1.99	0.65	0.84	42.95
1904.....	0.31	0.75	1.65	1.31	2.52	7.17	2.42	2.76	3.66	5.46	0.24	1.68	29.93
1905.....	0.73	0.49	2.28	0.51	6.61	6.59	2.46	6.82	4.43	3.68	1.33	0.31	36.24
1906.....	2.24	0.32	3.07	1.52	7.20	3.47	3.10	3.61	4.13	2.79	2.75	1.33	35.53
1907.....	1.85	0.75	1.95	1.20	3.27	3.80	1.12	5.68	3.65	0.77	1.33	0.42	25.79
1908.....	0.58	0.97	2.63	3.46	5.64	6.32	2.28	1.74	2.91	1.56	0.98	1.07	30.14
1909.....	1.03	1.61	1.28	3.42	3.00	2.96	2.20	2.22	6.84	2.63	5.42	1.46	34.07
Means..	1.00	1.28	2.04	2.58	4.37	4.66	3.47	3.26	3.93	3.22	1.67	1.48	32.96

These tables show the actual amount of precipitation for each month at the various stations for the past 15 to 20 years, and also the annual amount for each of the years, as well as the mean monthly and mean annual precipitation for the period.

The amount of rainfall during the growing season exerts the most influence on growing crops. The mean rainfall for the growing season and also the non-growing season is shown in the following table:

TABLE VI.—*Mean monthly precipitation for the growing and non-growing season for the entire period of record of each station, to 1909.*

Month.	Grantsburg.	Osceola.	Barron.	Downing	Eau Claire.	Red Wing.
April	2.78	2.33	2.36	2.74	2.58	2.28
May	4.11	4.27	4.29	4.55	4.37	3.63
June	4.80	4.75	4.79	4.71	4.66	4.34
July	4.40	4.12	3.88	4.06	3.47	3.37
August	3.45	3.28	3.45	3.65	3.26	3 65
September	4.18	4.05	3.14	3.77	3.93	3.94
Mean of the growing season	23.72	22.80	21.91	23.48	22.27	21.21
October	2.70	2.95	2.84	3.44	3.22	2.59
November	1.44	1.39	1.38	1.53	1.67	1.45
December	1.23	1.17	1.17	1.67	1.48	1.20
January	1.11	1.00	1.12	1.17	1.00	1.22
February	1.11	0.92	1.08	1.24	1.28	1.14
March	1.75	1.90	1.63	1.66	2.04	1.38
Mean of the non-growing season	9.34	9.33	9.22	10.51	10.69	8.98
Mean annual	33.06	32.13	31.13	33.99	32.96	30.19

The mean annual rainfall varies from 30.19 to 33.99 inches at the several stations. During the growing season from April to September the amount of rainfall is from 21.21 to 23.72 inches, the greatest fall occurring in May, June, and July, when most needed by the growing crops.

The amount of precipitation in the non-growing season from October to March, varies at the stations from 8.98 to 10.69 inches, being less than one-half the amount falling during the growing season. A little more than two-thirds of the annual rainfall, therefore, falls in the growing season. The monthly precipitation at Eau Claire and Osceola is illustrated in the diagram, fig. 13.

While the mean annual rainfall is generally from 30 to 33

inches there are occasional dry years when there is much less precipitation. During the 10 year period from 1893 to 1903, the precipitation during the driest year was 20.6 inches at Eau Claire and 27.1 inches at Barron, and during the wettest year of this 10 year period, there was a rainfall of 42.7 inches at Eau Claire and 36.3 inches at Barron. The records appear to show that the annual rainfall in the northeastern part of the area is more uniform from year to year than in the southwestern part.

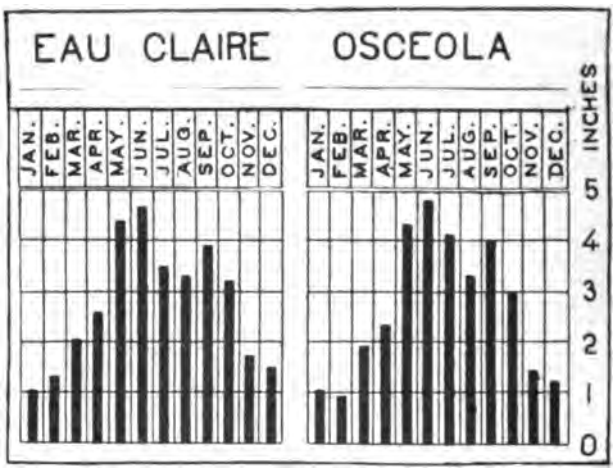

FIG. 13.—Diagram showing monthly precipitation at Eau Claire and Osceola.

It is of interest to compare the mean seasonal rainfall and mean seasonal temperatures of the area with that of the entire state and the adjoining states, as shown in the following table:

TABLE VII—*Table showing seasonal rainfall and temperatures.*

	Spring.		Summer.		Autumn.		Winter.	
	Mean temp. deg.	Mean precip. inches.	Mean temp. deg.	Mean precip. inches.	Mean temp. deg.	Mean precip. inches.	Mean temp. deg.	Mean precip. inches.
Northwestern Wis....	42.	8.6	67.3	12.6	46.1	7.9	13.7	3.7
Wisconsin.....	43.	8.3	68.0	11.2	47.	8.1	17.	3.9
Iowa.....	47.4	8.8	71.8	12.2	50.1	7.1	20.2	3.3
Northern Ill.....	48	9.5	72.	10.6	52.	8.3	23.	5.6
Northern Ind.....	49	9.9	72.3	10.4	52.9	9.2	26.	7.5

The summer months are the most important agriculturally and the table shows that for the summer season the mean temperature of the area is very favorable for agriculture, and is only a few degrees colder than the temperature of Northern Illinois, Northern Indiana, and Iowa and that the rainfall during the

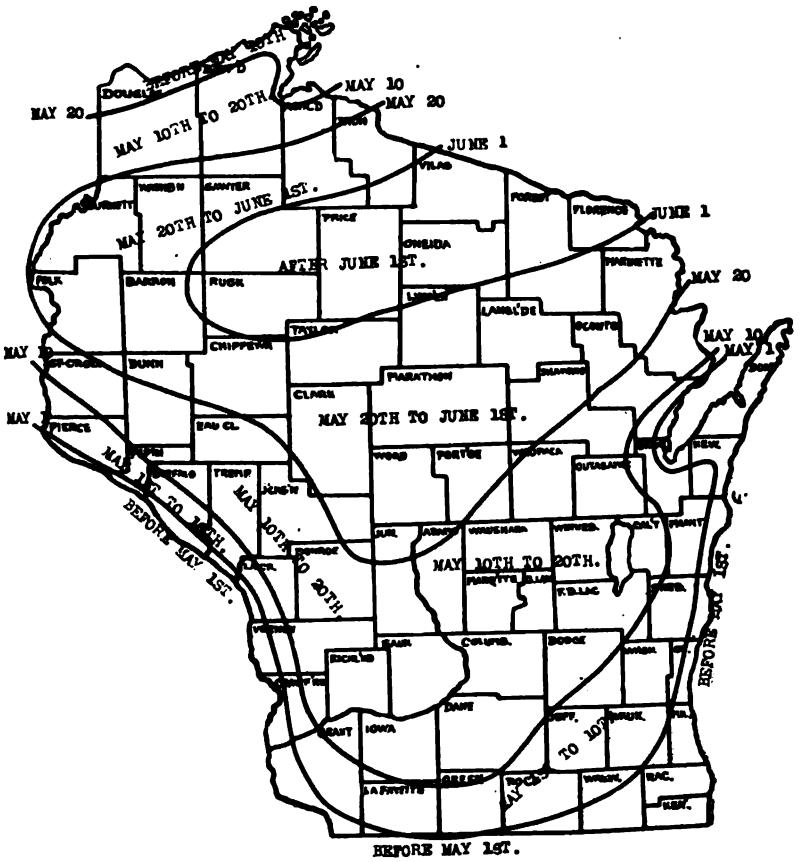

FIG. 14.—Average dates of last killing frosts in spring.

summer is more favorable than in the latter regions. The table shows that while the summer temperatures of the area closely approaches that of the region farther south, the winters are considerably drier, and colder than in the latitude of Northern Illinois.

TABLE VIII.—*Frost data.*

Stations.	Length of record, years.	Average date of	
		Last killing frost in spring.	First killing frost in autumn.
Barron	18	May 22	September 15
Grantsburg	17	May 14	September 19
Osceola	19	May 12	September 26
Downing	15	May 6	September 24
Eau Claire	19	May 10	October 1
Red Wing (Minn.)	8	May 2	October 5

Killing Frosts. The average date of last killing frost in the spring and first killing frost in the autumn is shown in the above table, complied from records extending over a period of 19 years.

The average period of immunity from frost at Barron is 115 days, at Grantsburg, 127 days, at Osceola, 134 days, at Downing, 140 days, at Eau Claire, 142 days, and at Red Wing, 155 days. The average period of immunity from frost in Rusk county is probably between 105 and 110 days, and in Pierce and Pepin counties about 150 to 155 days. In the two charts* of the state, figures 14 and 15, the several zones having similar frost data in the Spring and Autumn, are illustrated.

This period is sufficiently long for the growth of all common crops, with the possible exception of corn in the northeastern part of the area. In the northern part of Barron, and in Rusk, probably only the Wisconsin No. 8 variety of corn and flint can generally be brought to maturity. Corn for silage, of course, can be grown successfully in all parts of the area.

Other crops that are likely to be affected by the frost are tobacco and potatoes. Potatoes readily ripen within the period of 100 days or less. Tobacco is successfully grown in Chippewa and Barron counties. Tobacco, with proper rainfall and warm temperature conditions, will ripen in 70 to 80 days.

The tables of temperature and rainfall of the several stations furnish the detailed climatic data for the North Western area. It should be borne in mind by the farmer that the condition of

* Bartlett, in Bulletin 290, University of Wisconsin.

the soil is only one factor in the problem of agriculture and that conditons of temperature and amount of ranfall, especially for the growing season are also very important factors. The

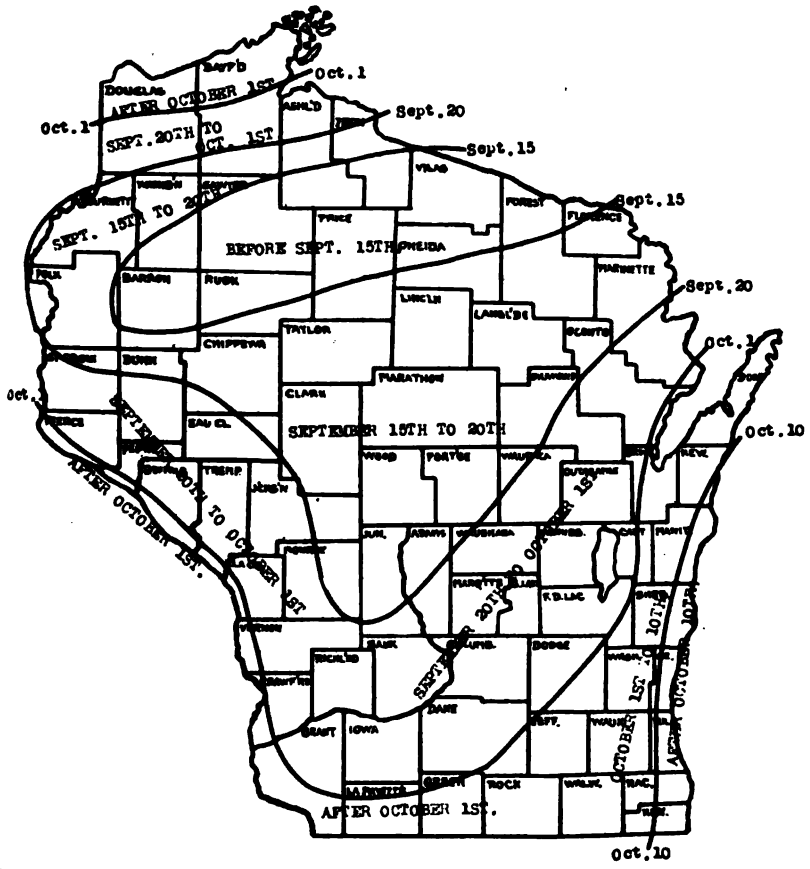

FIG. 15.—Average dates of first killing frosts in autumn.

kind of crop raised should be especially studied with respect to its climatic requirements, and comparisons should be made with the known conditions under which such crops have been grown in other localities.

CHAPTER III.

DESCRIPTION OF THE SOILS.

In the 6700 square miles of the area, there are fourteen kinds of soil as shown on the map. (Plate I in pocket.) Some of the soils are quite uniform in character over large areas while others are quite variable and lack uniformity.

Character and Origin of Soil.—The soil consists of mineral and organic material. The mineral portion of the soil originates through the disintegration and weathering of the stony material and the surface formations of the land, and the organic portions through the decay of animal and vegetable matter living upon and within the soil.

The most effective agent in the weathering of soils is water in its various forms, the changes of temperature, and the air. Water in the soil aids chemically by dissolving mineral matter, and mechanically by washing and wearing away loose soil material. The alternate freezing and thawing of water in the soil and rocks, in autumn and spring tend to break up the soil particles. Earthworms and other burrowing animals, aid materially in making soil. The growth of roots of the forest trees and also the smallest plants tend to split apart the rock particles and assist in soil formation.

Soil Erosion.—There is a constant process of wash by rains of the loose soil material from the higher levels and slopes of the hill sides to the valley bottoms, and thence by streams to still lower levels down the valleys. If rains are gentle, but little soil is washed away, but if rains are heavy, they may transport in a few hours enormous amounts of sand and mud to lower levels.

But little erosion can take place on nearly level or gently undulatng lands, but where slopes are steep the various bad features of erosion may develop. The lighter and more sandy soils, into which the rains can readily penetrate are not likely to be

appreciably eroded, even on the sloping lands, while the heavier clay soils and loams, unless carefully guarded may be subjected to much erosion. Most of this area on account of the loamy character of the soil and the gentle slope of the land is not likely to be much eroded, but in certain hilly portions, in the southwestern counties, the tendency to soil erosion should be checked as much as possible.

Sources of the Soils.—The soils have their source in the slow weathering and decomposition of the various formations of the area, such as the glacial drift, the loess, the alluvial plains, and the sandstone, the limestone and the crystalline rocks. The most important formations from which the soils are derived, are the surface formations of drift, loess and alluvial material, as these formations generally cover the bed-rock formations. In certain parts of the area, however, soils derived directly from the sandstone cover considerable areas. In the areas of the limestone and crystalline rocks, however surface formations of loess or drift are generally present. However the character of the surface formation is often largely determined by the underlying rock and hence the various geological formations are important factors in determining the character of the overlying soil.

Surface Soil and Sub-soil.—The surface soil generally containing more or less organic material, usually extends to depths of 6 to 8 inches. The subsoil immediately below the surface soil is important as the medium in which much of the soil moisture is stored. If the subsoil is such as to hold too little or too much moisture, the fertility of the soil is greatly decreased. It is important to know the character of the soil to a depth of 3 or 4 feet below the surface as well as of that portion which is turned by the plow.

Basis of Soil Classification.—The classification of soils and their separation and mapping into various types or phases, is based on the physical texture of the soil mainly due to the relative proportions of sand and clay present. Soils are generally referred to as clays, loams, or sands. A clay soil generally contains from 25 to 50 per cent of clay and the remainder silt, sand or gravel. A loam generally contains from 10 to 25 per cent of clay, a large proportion of silt and the remainder fine to coarse sand or gravel. A sand soil generally contains less than 10 per

cent of clay, a small amount of silt, and a large amount of fine to coarse sand. Between clays, loams and sands are many gradations such as phases of clay loams, silt loams and sandy loams. If a considerable amount of stone or gravel is present the soil is called stony or gravelly. Besides these soils there are the muck and peat soils containing a high percentage of decaying organic matter or humus, occuring in swamps and marshes.

Chemical Composition of the Soil.—The various chemical elements occuring in soil are oxygen, silicon, carbon sulphur, hydrogen, chlorine, phosphorus, nitrogen, fluorine, boron, aluminum, calcium, magnesium, potassium, sodium, iron and manganese. The oxygen hydrogen, carbon, chlorine, and nitrogen get into the soil from the atmosphere and the rains assisted by vegetation. The other elements are found in the rocks and surface formations from which the soils are derived. All the above named elements are generally in sufficient quantity to supply the required plant food, for crops. Only four of the elements, potassium, phosphorus, lime and nitrogen are generally considered important in the study of the soil fertility because these elements sometimes may be either lacking in sufficient quantity, or are not in an available form to supply plant food.

The names adopted for the various soil formations are local and have been selected from the names of rivers or townships where the soils occur, within this area, and within the area of north central Wisconsin immediately to the east.

The following table gives the approximate extent of the various soils mapped in the area:

TABLE IX.—*Areas of the soils.*

Soil.	Acres.	Soil.	Acres.
Chelsea loams	788.000	Chetek sandy loam	230.000
Hartland silt loam	556.000	Cushing loam	216.000
Auburn loams	482.000	Sterling sand	189.000
Baldwin silt loam	341 000	Swamp and marshland	160.000
Rice Lake loams	328.000	Milltown silt loam	69.000
Colby silt loam	323.000	Thornapple sandy loam	65.000
Kennan silk loam	316.000	Meridean sandy loam	44.000

Of the fourteen soils, seven are soils derived from the weathering of glacial drift, and physiographically are upland soils. The drift soils include the Colby silt loam, Chelsea loam, Kennan silt loam, Cushing loam, Thornapple sandy loam, Milltown silt

loam, and Baldwin silt loam. Other upland soils are the Auburn loam, developed mainly as residual soil on the sandstone and shale, and the Hartland silt loam developed on the loess. The soils which are of alluvial origin and mainly confined to the valley bottoms are the Rice Lake loam, the Meridean loam, the Chetek sandy loam, and the Sterling sand. Muck is characteristic of the marsh and swamp lands.

BALDWIN LOAMS.

Area.—The Baldwin loam occupies the central and eastern part of St. Croix county, and the adjoining northern part of Pierce county, and in general is developed over the limestone formations. It embraces a contiguous area of about 550 square miles, located in the most thickly populated portion of the region.

Surface.—In general the surface of the Baldwin loam is gently undulating with long gentle slopes. Considerable tracts are nearly level in eastern St. Croix county, in the towns of Springfield and Baldwin. The surface is gently undulating in Hammond, Erin Prairie and Emerald, with occasional lakes and ponds. In Gilman, Martell and Pleasant Valley the land varies from gently rolling to nearly level, with gentle slopes characterized by wet lands with poor drainage along the large streams and their many small tributaries. These small areas of wet lands along streams are found in nearly all the townships. In Eau Galle broad valleys, sloping gently upward to the higher land, are characteristic.

The area of this soil is mainly drained by the Eau Galle, Rush and Kinnickinnic rivers. In St. Croix county these streams flow through the broad uplands but further south in Pierce county they become trenched deeply into the limestone formations, first with narrow valleys and then farther south with broader valleys widening out to a mile or more. The Kinnickinnic river in the town of Kinnickinnic and River Falls has a broad valley bottom containing highly developed agricultural areas.

While no peat marshes of any size are associated with this type a conservative estimate of the area that would be benefitted by drainage exceeds 15 or 20 per cent. In the town of Eau Galle and Springfield and southern Baldwin considerable areas of wet lands are found. Boulders are found in the soil throughout

the area. In few cases, however, are the boulders so abundant as to interfere seriously with agriculture. Where the country has been opened for settlement some time the stone has been hauled off from the cultivated fields.

Forests.—The Baldwin loam was covered with dense forest in the eastern part of its area, and with meager forests in the northwestern part. In the densely wooded portion the trees were mainly hardwoods, consisting largely of maple, white oak, black oak, basswood, elm, ironwood and butternut. In the valleys, or wet lands, ash, soft maple and elm predominate. Here and there, however, on the upland slopes and in the valleys were tracts in which white pine was predominant. A belt, nearly two miles wide, between Woodville and Brookville was one of the largest of these pine tracts.

The pine has been wholly cut for several years. Considerable stands of dense hardwoods, however, still remain. Most of the 60 per cent of undeveloped land of this soil type in the towns of Cady, Eau Galle and Gilman, is still covered with forest.

In the towns of Hammond and Erin Prairie and vicinity were large tracts covered only with a meager forest growth consisting mainly of scrub oak, poplar, and hazelwood. These tracts were generally known as "prairies" and were the first lands in the region to be opened up to agriculture. In a few places only are there remnants of these thinly forested tracts. At present from 80 to 90 per cent of these thinly forested tracts are under cultivation.

Soil.—In general the surface eight inches of the Baldwin loam is a silt loam or loam with sufficient amount of organic matter to give it a medieum dark brown color. This type is found over a large part of the area of Northwestern Wisconsin, mainly on the higher land as distinguished from the areas nearer streams and along slopes.

The subsoil from eight to twenty-four inches is usually a fine grained sandy loam. In places the subsoil is bluish in color where the underlying limestone is Trenton, and in such places it is quite retentive of moisture. At lower depths gravelly material is associated with much of the soil. The peculiar structure of the subsoil in places where Trenton shale is present gives rise to some important problems of drainage which will be discussed in another place. Underlying this loam is mainly a lime-

stone bed rock. In portions of Pierce county, mainly in River Falls and Martell, and in St. Croix county, in Kinnickinnic and Troy this limestone is the Trenton formation. In the remainder of the area, with a few exceptional areas of sandstone, the underlying rock is limestone of the Lower Magnesian formation.

There are slight variations of this soil which differ from the dominant type just described.

A portion of the Baldwin soil area has been designated as a prairie though it differs essentially from a true prairie in the absence of black prairie soil. A true prairie soil contains a relatively large amount of organic matter, as can be observed by the black color of soil to considerale depths of five or twenty feet, or even more. This black organic matter represents past accumulation of prairie grass and other vegetation that has grown up and accumulated in the soil there to decay during long periods of time. Rainfall is an important factor, and also topography, in developing a prairie vegetation. When rainfall exceeds 25 inches the native vegetation tends more to develop light forest growth and consequently less grass vegetation.

The surface soil on the openings or "prairie" tracts is medium heavy loam carrying small amount of coarse gravelly particles. It has a grayish to dark gray color with a fair amount of organic matter as indicated by chemical analyses. The subsoil becomes somewhat more clayey at about two feet, and is usually of yellowish color. The organic content in the surface eight inches in the so-called prairie of Hammond and Erin Prairie, as shown by chemical analysis, is practically the same as in the heavily forested soil in Springfield and Eau Galle. Below 22 to 24 inches the soil in most cases becomes somewhat gravelly in places but the clay content with it makes the soil at the lower depth more compact.

The content of medium and fine sand in this soil makes it fairly loose and open, yet some areas show that tile drainage is needed to remove surplus underground water. This is especially true where the land is nearly level.

Aside from the marshy tracts, there is perhaps no section within this area described in this report where necessity of drainage is of so much importance as in this section. Surface ditching would be a considerable help in many areas but eventually tile drainage must be resorted to. Up to the present time little

has been attempted in the way of tiling. Many farmers are in doubt as to the efficiency of tile drainage, fearing that the heavy subsoil would prevent downward passage of water fast enough or that the tile will fill up and hence be of no value. General practice elsewhere has long demonstrated the great value of tile drainage.

In speaking of drainage it is the popular notion generally that only low lands and marshes are areas most in need of drainage. In this area much of the land requiring drainage is upland, some even on highest table land, where the fall for natural drainage would ordinarily be sufficient. The subsoil, however, in these wet upland tracts is usually the tenacious Trenton clay already referred to. When this clay becomes thoroughly wet it is impervious, causing water-logging of soil at the surface.

The results of mechanical analyses of composite samples of the soil and subsoil are shown in the following table:

TABLE XI.—*Mechanical analysis of the Baldwin silt loams.*

No.	Location.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
130	Springfield, St. Croix Co....	Soil.....	.0	6.2	5.9	9.4	12.8	55.4	9.9
130	Springfield, St. Croix Co....	Subsoil..	.3	10.6	11.5	17.2	11.2	38.0	11.0
122	Eau Galle, St. Croix Co....	Soil.....	.0	8.8	9.11	13.1	12.5	45.7	10.3
122	Eau Galle, St. Croix Co....	Subsoil...	.4	9.0	11.7	15.4	15.4	32.5	15.2
125	Erin Prairie, St. Croix Co....	Soil.....	.0	6.9	8.9	11.0	15.5	48.0	9.3
125	Erin Prairie, St. Croix Co....	Subsoil...	.3	7.9	20.0	16.4	15.0	32.4	16.0

Agriculture.—The crops raised are very largely oats, wheat, some barley and flax. Wheat is important only in Hammond, Erin Prairie, and adjacent territory. Corn is raised mainly in western St. Croix and on the uplands in Troy, Kinnickinnic in northern Pierce county. In the remainder of area the corn acreage is considerably less. The leading exports from the farm consist of dairy products and live stock, mainly hogs, beef cattle, and sheep. The dairy product is mainly cream which is usually collected and sent to local creamery, run on a co-operative basis. The Baldwin co-operative creamery is one of the largest in the state.

In Rush River and Pleasant Valley are areas of sandy loam of limited extent. This soil with its large area of slopes is well adapted to grazing and pasture. The Baldwin loam is well adapted for dairying and sheep raising. Fifty per cent of the wool raised in northwestern Wisconsin is raised on the Baldwin soil. Pasture lands are well watered as a rule and retain good feeding ground even during dry seasons. Large tracts are devoted to hay, timothy, redtop, and some clovers.

The grain and hay is generally fed on the farms. Corn has not been extensively grown but a variety like Wisconsin No. 8 ought to be tried. The average period of immunity from frost is 135 to 145 days in Pierce and St. Croix county. There is no question but what corn would mature. Dairy farmers will also soon find corn silage an excellent feed for dairy stock. More attention should be given to proper rotation of crops on this soil. Hay fields in which timothy was grown for three to five years were common. When this old sod is plowed again the physical condition of the soil is far from what it should be. After lying so long in sod a good application of farm manure is needed to develop sufficient fertility to produce a good grain or corn crop.

A good rotation is to include clover or alfalfa in the rotation either alone or with red top and timothy and allow these crops to occupy land not longer than two years out of a possible four or five year rotation. In connection with growing alfalfa it might be mentioned that when farmers have difficulty in obtaining a stand it is due probably to lack in the soil of the bacterial organism which causes the formation of tubercles or nodules on the roots. The soil in such cases requires inoculation from fields where alfalfa is growing. When this is impossible inoculation by scattering soil from the sweet clover plant does equally well. The organisms from alfalfa and sweet clover are identical. Sweet clover grows along the roadsides as a tall, rank weed with whitish blossom. Around Centerville, and also near Beldenville areas of sweet clover were observed.

Ground limestone at the rate of 2000 pounds per acre will be beneficial on many of these soils where soil acidity has developed, the acidity being shown by the development of a rather healthy growth of yellow sorrel and sheep sorrel. When ground limestone is unobtainable, unslaked lime will do equally well.

The application of limestone and phosphate fertilizer where

needed together with the very general growing of leguminous crops and the application of stable manure applied directly from the stable and a proper rotation of crops will maintain fertility of the soil as well as insure profitable crop yields.

The so-called "openings" or "prairies" in Hammond and Erin Prairie have been and are still the most important grain raising sections in the region. When first opened to agriculture, wheat was about the only crop harvested and sold from the farm. About 1890, however, a change came about and less wheat was sown, partly due to decrease of yield and partly to ravages of the chinch bug. During the last 15 years there was a tendency to grow more of the other grains and a rotation including oats, barley, and wheat in order named became the system. At present this order of farming still applies to the town of Erin and to a smaller degree elsewhere. At present the tendency elsewhere is away from the exclusive grain farming and towards a diversified farming instead. Corn is becoming more important and stock is raised for dairy and beef purposes.

The farmers have learned from experience that an exclusive grain farming system which does not involve the return of abundant fertilizing material during course of rotation, has lowered the yield per acre so much that in some instances the crop did not pay for the labor expended in caring for it. With a more systematic rotation, including the more general growing of clover and application of farm yard manures the yield per acre has been perceptibly increased.

The ideal system of farm practice requires the keeping of considerable stock and the maintenance of a balanced system of rotation of crops in which some grains, wheat or oats, flax, etc., and clover would be included. The farm products exported would consist mainly of cream, butter, or fat stock. Even when grain is largely the important crop exported, the fertility of the soil and production per acre can also be maintained. Such a system would involve a rotation of crops in which clover would occupy land at least one-quarter of the rotation period, and a generous application of manure and lime or phosphate occasionally when needed. Where grain raising is the principal industry and where, as shown by experimentation, a phosphate fertilizer is needed to increase the yield the phosphate should be applied to the soil in combination with stable manure. The

manure will aid greatly in making the phosphorous available. The organic matter in the soil also acts similarly to manure in gradually liberating the phosphorous in the fertilizer. Where the phosphate fertilizer is found to be beneficial, applications of about 1000 pounds of ground rock phosphate per acre followed by lighter application of 200 to 300 pounds during each rotation period is generally found to be sufficient. The supply of nitrogen to the soil can be maintained as already stated by the growth of leguminous crops.

Land Values.—The usual price of improved land on this soil type is $60 to $100 per acre, and occasionally higher prices. As a rule farms devoted to grain raising bring lower prices than those devoted to dairying and stock raising.

COLBY SILT LOAM.

Area.—This soil formation occupies a large part of Barron county, with small areas in adjoining counties. In Chippewa county in the vicinity of Stanley and Boyd is a considerable area of this soil formation. This soil has an area of 525 to 550 square miles, 85 per cent of which is within Barron county. It has also a wide extent farther east, in Clark, Taylor, Marathon, and Wood counties, as described in the report on the soils of North Central Wisconsin.

Surface.—The surface of this soil is gently rolling and undulating. See Plates VI and VII. Somewhat hilly areas are found adjacent to streams and rivers, as for example along the Hay river and Turtle creek, where tracts nearly one-half mile in width are quite broken and uneven. As a general rule, however, none of this land is too hilly for cultivation. The soil is generally well drained, and within its area lakes and swamps are very rare.

In many instances the very gently sloping fields would be benefited by tile drainage. While the character of the subsoil is generally favorable to natural underdrainage, yet there are exceptions where the soil remains too wet and cold during the growing season to develop good crops and in these cases tiling or other methods of farm drainage should be practiced.

Forests.—This soil was formerly forested with a heavy stand of mixed timber including maple, basswood, oak, with some elm and ash among the hardwoods, and white pine, hemlock, and

some balsam. The pine was cut first and practically none remains at present. Among the hardwoods, considerable tracts of maple, basswood, and elm are found throughout the entire area.

Soil.—The soil of this formation to a depth of eight inches is a silt loam. It contains enough silty material to make it a quite friable and open soil. Some boulders and coarse material are associated with it. The subsoil is yellow to buff colored silt loam that becomes slightly more clayey with depth. Both surface and subsoil are quite uniform in physical character.

The following table gives the results of mechanical analyses of the soil and subsoil of this type:

TABLE XII.—*Mechanical analysis of Colby silt loam.*

No.	Location.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
154	Barron Co.....	Soil.....	.1	3.2	4.0	3.6	12.6	61.9	13.6
154	Barron Co.....	Subsoil...	.0	3.2	4.7	3.2	19.7	51.2	17.4
119	Chippewa Co....	Soil.....	.0	2.5	1.6	3.3	20.3	58.7	13.7
119	Chippewa Co....	Subsoil...	.0	0.6	.5	.7	20.5	63.5	14.0

The Colby silt loam is a glacial drift soil derived from the weathering of the old drift formations. The material of the drift consists of clay, sand, and boulders from the crystalline or granite formation and sandstone. The soil is free from debris derived from limestone formation, and in this regard differs from the Baldwin loam which contains much limestone material. While the Colby silt loam generally contains sufficient lime derived from the weathering of crystalline formation the content of lime in the soil water and in the soil itself is probably generally lower than in soils developed upon limestone drift. An acid condition, however, of this soil is of rare occurrence, at present, though acidity may develop later.

The soil bears well, is naturaly well drained on account of its rolling surface and works up easily as a rule. It is one of the most fertile soils of northern Wisconsin. It is not known to pack or become puddled after heavy rains. At the present time less than one-half of the land in farms is under cultivation, but the clearing of land for agricultural purposes is going on rapidly.

Agriculture.—Dairying is the leading industry on this soil

VIEW OF COLBY SILT LOAM, NORTH OF CADOTT, CHIPPEWA COUNTY.
Shows general character of farm buildings developed in a dairy and general farming section.

VIEW OF COLBY SILT LOAM, SOUTHWEST OF RICE LAKE, BARRON COUNTY.
Shows the deep, broad valleys developed in the old drift.

type at present and will probably continue to increase in importance as the land is brought under the plow. The soil is especially well adapted to live stock. The tract furnishes abundant pasturage, and springs and streams afford plenty of water. Clover and other tame hay produce excellent yields.

Oats are the leading grain raised. Barley and wheat are grown to a small extent and give good yields. Corn has not been raised extensively on this soil, though both soil and climate are favorable. A large acreage is devoted to pasture, clover, and timothy. Potatoes are a good crop for export. Sugar beets and other root crops are grown quite extensively. The acreage of corn should be increased not alone for its value as silage and grain, but also for its value as a rotation crop with oats and the grasses.

Land Values.—The prices at which improved land is held varies from $60 to $100 per acre. Uncleared land of this type is generally held at $15 to $25 per acre. Good stands of timber still remain on large tracts of this soil type.

KENNAN SILT LOAM.

Area.—The Kennan silt loam lies in the northeastern part of Chippewa county and over a large part of Rusk county. It is mainly the gently undulating ground moraine area of the latest drift sheet. This soil type extends over a large portion of Price, Taylor and Lincoln counties as described in the soil report of North Central Wisconsin.

Surface Features.—The surface of the soil is generally rolling or slightly undulating with here and there, throughout the area, broad stretches that are quite level. Nearly all of the soil can be brought under cultivation. Large swamp and marsh areas are prominently associated with this type in portions of Rusk county. Nearly one-fourth of some of the towns in Rusk, as indicated on the soil map, are marsh and wet soil. The tract is drained mainly by the Chippewa and Flambeau rivers. See map of eastern part of Rusk county, figure 16.

Native Forest.—This silt loam developed some of the finest stands of hardwoods in the state. Pine was not relatively abundant, but considerable hemlock was interspersed with the hardwood. Cedars are common along low river areas.

At present but little of the original forest remains. The pine has been wholly removed, and at present the hemlock and hardwoods are being rapidly cut out. Forest fires have caused much damage in places. The wooded section of northeastern Rusk county suffered especially from wind storms, at an early date as indicated by numerous tracts of windfalls. Large mills for sawing hardwood and hemlock are located at Atlanta, Ladysmith, Ingram, Hawkins, Ruby, and Arnold.

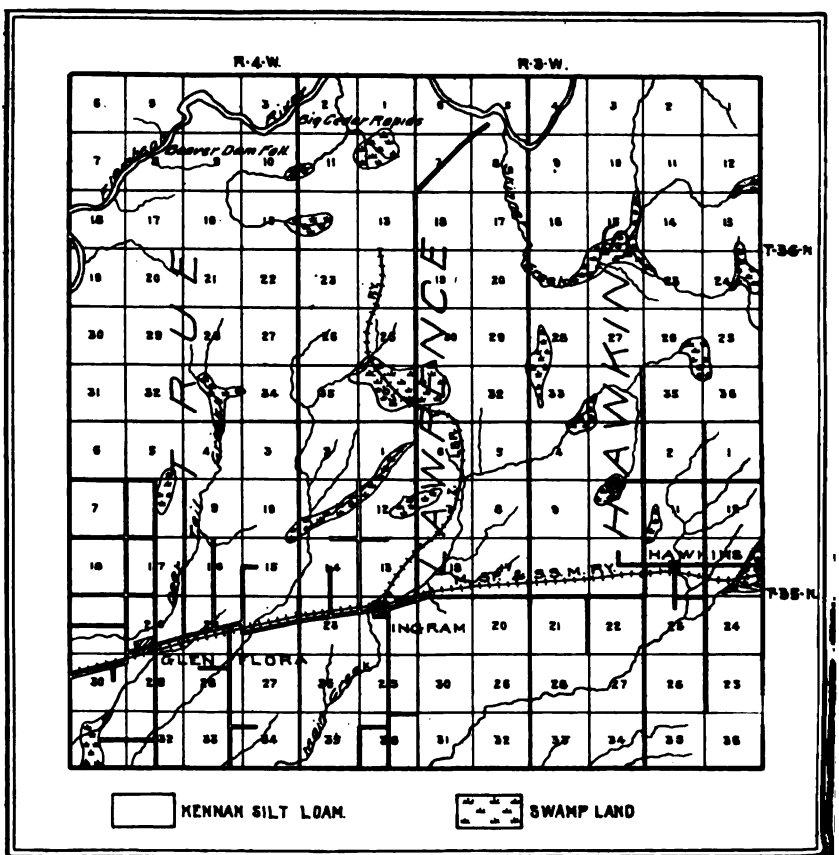

FIG. 16.—Soil map of northeastern Rusk county.

Soil.—The surface soil to depth of eight inches is a silt loam, somewhat grayish in color and quite free from stone. The subsoil is silt loam, carrying considerable clay. As shown by mechanical analyses most of the soil is very fine sand, silt and clay.

Both surface and subsoil are quite uniform over the area. Some stone occurs in the soil and in some places interferes with agriculture. These stony areas are found in low places or bordering marshes, and in a few cases on the uplands. Some of the soil on the gentle slopes will require tile drainage to get the best crop results.

The results of the mechanical analyses of samples of the soil and subsoil are shown in the following table:

TABLE XIII.—*Mechanical analyses of Kennan silt loam.*

No.	Location.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
120	Chippewa Co.....	Soil.....	.0	2.5	1 8	3.0	18.5	60.3	14.7
120	Chippewa Co.....	Subsoil...	.0	.7	.7	1.3	29.1	52.6	15.4
165	Rusk Co.....	Soil.....	.1	2.3	2.4	4.0	12.1	67.7	11.2
165	Rusk Co.....	Subsoil...	.2	1.9	2.2	3.6	25.1	55.3	11.5

Agriculture.—This soil area is opening up and developing rapidly into a typical dairy section, for which purpose it is well adapted. The grasses grow exceptionally well, especially clovers, timothy, and red top. The many streams furnish abundance of water for stock. Common wells 15 to 30 feet deep furnish a supply of water for the home. Blooded stock is being introduced, Holsteins and other dairy types being most prominent. Sheep have been introduced and pay well.

Small grains such as oats, and barley yield abundantly, the yield of each being 30 to 40 bushels per acre. Corn has not been grown to a large extent. With the increase in the dairy industry more corn, especially for ensilage, will be grown. Special crops like seed peas for canning purposes have been found to do well on this soil. A large farm in southeastern Rusk has been developed for growing peas for seed and canning purposes. The common pea could be successfully raised for fattening hogs and other stock in place of corn.

In Chippewa county tobacco has been grown successfully on this silt loam soil. The acreage of both the tobacco and pea crops will be materially increased in these counties in the future.

The chemical analysis of a sample of virgin soil collected from northwestern Chippewa county shows that the soil is well supplied with essential plant food elements. This should not be

taken however, to indicate that excessive grain cropping without proper attention to rotation can be practiced on it. The present up-to-date agriculturist should profit by the experiences of others in the past and maintain the fertility of his soil.

The Kennan clay loam is very largely wild land, either thickly forested with hardwoods of cut-over land. Probably less than 5 per cent of this soil in Chippewa county is under cultivation and less than 3 per cent in Rusk.

The cost of clearing this land ranges from 15 to 30 dollars per acre, depending upon the amount of slashing and stumpage found on it. The wood not fit for lumber is usually sold as fuel to the paper and saw mills and the profit received from this source helps considerably to defray cost of clearing the land.

Land Values.—The wild land, with little or no merchantable timber, is generally held at $10 to $20 per acre, depending on location and accessibility. Cleared farms, with buildings, are generally held at $50 to $80 per acre.

CHELSEA LOAMS.

Area.—The Chelsea loams form a belt of considerable width in northeastern Chippewa county, western Rusk county, northwestern Barron county, and a large portion of Polk county. This soil type, as defined, consists essentially of undulating terminal moraine of the latest period of glacial drift. The Chelsea soil covers a large area farther east, in Taylor, Lincoln and Langlade counties, as described in the soil report of North Central Wisconsin.

Surface Features.—Because of the manner in which this soil type was formed, as glacial moraines, considerable variation in the surface features have developed. In general, the land is undulating with belts of low ridges and billowy hills, associated with basin-like depressions, swamps and small lakes and ponds. See Plate VIII. Here and there, throughout, are stretches of more level areas. The hilly land is usually more stony than the level areas, the latter usually being either more sandy or more clayey than the former.

In western Rusk and eastern Barron counties are relatively high uplands consisting of hard quartzite formations. On the slopes of these ridges there is usually much loose stone. Flambeau Ridge in northern Chippewa county is a prominent feature

VIEW OF CHELSEA LOAM, EST OF TURTLE LAKE, POLK COUNTY.
Shows characteristic ...ew of terminal moraine topography.

of the topography. In the west central part of Polk county are broad upland areas of trap rocks, showing abundant outcrops of rock ledges.

Native Forest.—The Chelsea loam was originally covered with a dense growth of hardwoods, hemlock, and pine. Practically all the pine has been cut for a number of years. Large bodies of hardwoods and hemlock, however, still remain. The hardwoods were chiefly maple, oak, birch, basswood, and elm. The amount of hemlock was generally equal to or greater than the combined hardwoods.

On the lighter phases of the soil, some scrub oak was developed. In the swampy and wet tracts, spruce, ash, soft maple, and ash are common.

Soil.—The Chelsea loam varies from a sandy to silty loam in the surface eight inches, with a somewhat heavier subsoil of loam from eight to thirty inches. The surface soil is grayish to medium dark in color, and the subsoil lighter colored. The soil is not uniform over the area as mapped, but varies from a sandy loam to silt loam.

The soil is derived from the weathering of glacial material, consisting of sand, clay, and boulders of crystalline and sandstone formations. No limestone material occurs in the soil.

A detailed soil map of the area should show a complex association of sandy loam and silt loam type of soils. In some places the heavier silt loams prevail, in other places, the sandy loams.

The surface feature of the soil as already described are uneven and undulating, and the variation in the physical texture of the soil, is strongly influenced by the topography.

Stone and boulders are a common occurrence in the soil. Generally the stone is found in narrow belts and patches, and occasionally becomes a serious handicap to the development of agriculture. The low marshy areas are often quite stony.

The mechanical analysis of the soil is shown in the following table:

TABLE XIV.—*Mechanical analysis of Chelsea loam.*

No.	Location.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
140	Polk Co.....	Soil.....	0.1	5.7	4.0	4.0	19.4	53.6	12.8
140	Polk Co.....	Subsoil...	.0	3.3	3.2	3.0	27.2	46.3	16.8
136	Polk Co.....	Soil.....	.2	7.4	4.3	4.2	14.2	57.3	11.8

Agriculture.—The soil is well adapted for certain lines of agricultural development. Chief among these is dairying together with sheep and stock raising. The rougher and more hilly portions are admirably adapted for grazing purposes. In some few localities sheep and goat raising has already assumed importance. In the newer sections sheep and young stock will be found profitable while the cultivable areas are being cleared for the plow.

Dairying is now the most important industry and will become more important in the future. Several factors are strongly favorable to dairy farming on this soil. In the first place, pasturage, as stated above, is abundant, and all grasses thrive readily. Clovers, timothy, and alfalfa do exceptionally well for hay crops.

Oats are the principal grain crop, the average yield being about 40 bushels per acre. Barley and wheat are raised to some extent. The acreage of corn has markedly increased during the last 10 years, being more than double that of 10 years ago. The average yield per acre of wheat is about 15 bushels, of rye 16 bushels, of barley 30 bushels, and corn 40 bushels. The yield of hay is generally from one and one-half to two tons per acre. Excellent potatoes are grown, the usual yield being 100 to 150 bushels per acre.

The grains and forage crops are generally fed on the farms instead of being marketed. Concentrated feed stuffs are purchased besides, especialy where the dairy business is continued throughout the year.

If the dairying system of farming continues in its rapid development, the question of maintaining the fertility of the soil will be easily solved. A low stage of fertility like that which tends to be developed by excessive grain cropping, is not likely to be developed on farms where much stock is raised and where

VIEW OF MILLTOWN LOAM, NEAR RANGE, POLK COUNTY.
Shows typical dairy farm with buildings, including silo.

the return of plant food to the soil is made in the form of barn yard manure.

Only a small percentage, probably less than 5 per cent, of this soil type in Chippewa, Rusk and northeastern Polk counties is opened to agriculture. Part of the uncleared area is still covered with dense forests, and part of it is cut-over land. Most of the unsettled area is as good for agricultural purposes, as that which has already been brought under the plow.

Land Values.—The land still unopened to agriculture, is held at various prices, varying from $8 to $15 per acre, the price depending on location, amount of merchantable timber, etc. Cleared land generally sells for $40 to $60 per acre, depending on the character of the farm buildings. As already described, the soil of this type and its surface features are quite variable, and nearly all farms are likely to contain some land of relatively low agricultural value with the land of very good character.

MILLTOWN LOAM.

Area.—The Milltown loam is mainly within Polk county, occurring in bodies of considerable extent in the region about Milltown, Centuria, and Sand Lake; farther east in the southern part of the town of Georgetown is a large body and also a considerable area in the region about Joel and Range; there is also a small body in the town of Farmington. The total area of this type is about 110 square miles.

Surface.—The surface varies from level to slightly undulating, containing depressions or basins, some of which are occupied by lakes, ponds, and small marshes. The topography is the characteristic "pitted plain" topography of glacial drift areas. The depressions and basins, however, occupy only a relatively small proportion of the tract, most of the land being nearly level to slightly rolling, see Plate IX.

Native Forest.—The soil was originally covered with dense hardwoods, with some pine and hemlock. The hardwoods were mainly, maple, birch, oak, elm and basswood. Some poplar and pine grew along the streams. The pine has been wholly cut and most of the hardwoods have been removed. Practically all of this land is set off into farms and probably 40 to 50 per cent of the land is now under cultivation.

Soil.—The surface four to eight inches of this soil is generally a fine, sandy loam or loam, grayish to brownish in color. The subsoil is grayish yellow loam, quite similar in texture to the surface soil to a varying depth of one to three feet, at which depth much sand and gravel is often met with. The mechanical analysis shows this soil to consist largely of very fine sand and silt. In some places the soil is quite stony, the stone being glacial boulders mainly of granite rock. Like all other glacial soils in the area the type contains a variable amount of gravel in the soil, the gravel being more abundant in the subsoil than in the surface soil. The material of the drift consists wholly of granite and sandstone material mixed with silty clay, and sand. The subsoil conditions are favorable to good underdrainage and the surface soil is capable of holding sufficient soil moisture, for all crops, with the ordinary rainfall. The type is an easy one to cultivate, and on the whole is one of the most fertile soils in the region. It has already developed into one of the most thrifty agricultural sections of Polk county.

The results of mechanical analyses of a sample of the soil and subsoil is shown in the following table:

TABLE XXIX.—*Mechanical analysis of Milltown loam.*

No.	Locality.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
146	Polk Co.....	Soil.....	.0	7.7	9.9	14.2	23.9	36.0	8.0
146	Polk Co.....	Subsoil...	.0	9.9	12.8	17 4	22.0	24.7	13.2

Agriculture.—The Milltown loam is well adapted to diversified farming and is now quite generally devoted to dairying and grain raising. The leading grain is oats, with a much smaller acreage of barley, wheat, corn, and rye. The average yield of wheat is 18 to 22 bushels per acre, of oats 40 to 50 bushels, barley 35 to 40 bushels, and corn 30 to 35 bushels. The yield of hay is generally 1½ to 2 tons yer acre. The acreage to potatoes is relatively small, the usual yield being 100 to 150 bushels per acre.

Dairying is the leading industry on this type of soil as it is on all the soils throughout Polk county. The value of dairy

products from the farm on this type is more than that of the grain crops raised.

Stock raising is also important, the principal stock sold from the farm being cattle and hogs, with sheep relatively unimportant.

The principal dairy product is creamery butter, though cheese is the principal product in the Farmington area. The cream is quite generally separated on the farm. Besides supplying local creameries, large shipments of cream and milk are sent to St. Paul and Minneapolis.

This soil type is well adapted to dairying. Silos are common and indicate a progressive dairy system. The grade of dairy stock is gradually being improved, but more attention should be paid to this subject, and more rapid improvements made. The improvement of dairy stock is very important and is well worth the closest attention by the farmer.

The practice of extensive dairying on this type has kept up the soil to a good grade of fertility as is shown by the good yields of grain.

Land Values.—The farm lands on this type are of good value. Unimproved land is generally held at $20 to $30 per acre. Improved land is usually held at $60 to $80 per acre. Most of the land of this type has already been divided into farms, though a large percentage of the farm area is still uncleared.

THORNAPPLE SANDY LOAM.

Area.—The Thornapple sandy loam is mainly within Rusk and Chippewa counties, the largest area mapped being in the town of Thornapple, Rusk county. It is typically developed on the so-called "Peninsula" between the Flambeau and Chippewa rivers. The boundaries fixed for this soil formation on the map are only approximate. Within these soil areas as mapped are several phases of sandy loams, but owing to the fact that large portions of this area are not well settled, exact boundaries could not be located with any degree of accuracy.

Surface Features.—While in a general way the surface of this soil is nearly level to undulating, there as areas which are hilly, having a sort of choppy appearance. The uneven tracts are characterized by small knob-like elevations and some depres-

sions. Marshes and lakes are common features within the general area of this soil.

The surface of this soil was determined largely by the ice which moved over this tract. The erosion by streams thus far has not caused much change in the original topography left after the deposition of the glacial drift sheet.

Forest.—Most of this soil was originally covered with forest trees, consisting mainly of black oak, and white pine. Within the general area are ridges of heavier soil which developed good stands of hardwoods. The heavy pine timber has been cut, and aside from a few hard wood ridges yet remaining, the area is now mainly covered with a thicket of poplar, birch, small oak, and pin cherry. On the level areas where the soil is sandier, thick brush and sweet ferns are common.

Soil.—Both the surface soil and subsoil are sandy loam, consisting of a large proportion of fine to coarse sand and a small proportion of silt and clay. The surface soil to a depth of six or eight inches contains sufficient organic material to give it a medium dark to grayish color. The subsoil is light colored, grayish to yellowish, and consists mainly of sand with a little clay to a considerable depth.

The results of the mechanical analysis of the soil and subsoil are shown in the following table:

TABLE XV.—*Mechanical analysis of Thornapple sandy loam.*

No.	Location.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
164	Rusk Co.....	Soil.....	1.1	28.2	22.7	15.7	5.6	20.3	6.5
163	Rusk Co.....	Soil.....	.1	15.1	23.5	31.8	11.1	13.6	5.9
163	Rusk Co.....	Subsoil...	.4	13.6	23.3	33.8	10.1	14.6	4.6

There are slight variations from the general type. The level stretches along the rivers are nearly flat, mostly pine land, and the soil contains much coarse sand. Over the undulating areas, some stone occurs and there is a larger proportion of fine sand and silt in the soil, and hardwood forest mixed with the pine was developed.

Agriculture.—The soil is well adapted to dairying and to the raising of such grains as oats, buckwheat, and barley. Corn has been raised and matured successfully. The soil may be

worked earlier in spring than the heavier soils and is not apt to be cold in spring months when corn wants a warm seed bed. There is, however, some danger from drought on sandy phases during dry season on account of porous nature of the soil.

Tobacco and potatoes are grown with good results. Clover hay yields plentifully. Alfalfa and mammoth clover should be grown on this soil. So far little has been attempted in the way of growing alfalfa and other special crops.

Only a small percentage of the area of this soil is now under cultivation. The farms already developed are in a thrifty condition and prove the soil well adapted to general agriculture with dairying and potato raising as the principal industries.

Land Values.—The open land is more easily cleared than the dense hardwood areas. The wild land is generally held at $10 to $20 per acre, and the cleared land generally from $40 to $60 per acre.

CUSHING LOAMS.

Area.—The Cushing loams lie in the western part of Polk and St. Croix counties. They lie wholly within the area of the undulating terminal moraines of the latest drift sheet.

Surface.—The surface of this soil is more or less hilly, with low hills associated with depressions, lakes and ponds. The topography is the characteristic terminal moraine topography, with abrupt basins and steeply sloping ridges. Surrounding many of the lakes, and also adjacent to streams are many small marshes, most of which are too small to be shown on the map.

Throughout the area, are many nearly level areas which are usually either quite sandy or quite clayey. Stone and boulders are more common in the uneven lands than over the level tracts, but some of the low and marshy tracts are also stony. The stones are not usually so abundant as to interfere seriously with agriculture.

Native Forest.—This soil was quite generally covered with a dense growth of hardwoods, pine, and hemlock. As elsewhere in this region, the pine has been wholly cut. The hardwoods and hemlock remain only in isolated tracts. The hardwoods were chiefly maple, oak, elm, birch, and basswood. On the lighter phases of the loam the white pine predominated, while on the heavier soil the hardwoods were most abundant.

Soil.—The surface eight inches of this soil consists generally of a loam. From eight to twenty-four inches the subsoil becomes more clayey and also carries a larger content of gravelly material than the surface soil.

This soil, however, varies considerably both in the surface and subsurface layers. Some tracts contain a large percentage of medium and fine sand and are a sandy loam. These sandy areas are usually rolling though in some places adjoining stream bottoms the surface is more nearly level and also more sandy.

The soil is derived from the weathering of glacial drift in which limestone debris is generally an abundant constituent. This soil area therefore is confined to that part of the region containing limestone bearing drift, or is within the general area in which limestone is the prevailing underlying rock.

A large area of hilly, sandy loam occurs in the town of Somerset in St. Croix county and around Dresser Junction in Polk county.

Another variety of soil with a high content of clay and silt occurs in patches here and there within the tract mapped as Cushing loam. These areas are less undulating and somewhat stony in places but are generally well improved. In Polk county, southwest of Clayton, in Black Brook, and in Alden, south of Little Falls, are areas of these heavy loams. In the preliminary soil mapping done here neither the sandy nor the clayey phases of the loam have been separated from one another. To do so with any degree of accuracy would require a very detailed survey.

TABLE XVI.—*Mechanical analysis of Cushing loams.*

No.	Location.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
138	Polk Co.....	Soil.....	.0	5.1	4.7	16.0	11.2	62.5	10.4
138	Polk Co.....	Subsoil...	.1	5.7	5.4	6.4	18.9	45.5	17.8
142	Polk Co.....	Soil.....	.7	9.5	9.3	18.3	25.4	28.5	10.2
142	Polk Co.....	Subsoil...	.5	6.9	8.6	18.2	21.8	26.4	17.6
151	Polk Co.....	Soil.....	.1	12.6	15.4	16.2	10.7	35.8	8.9
151	Polk Co.....	Subsoil...	.0	13.2	12.9	14.2	13.4	31.3	14.4
127	St. Croix Co....	Soil.....	.5	9.6	8.6	9.5	21.8	43.3	6.4
127	St. Croix Co....	Subsoil...	.4	8.4	7.8	8.8	24.5	36.2	13.8

Agriculture.—The Cushing loams are well adapted to general agriculture. They are especially well adapted to dairying and stock raising. The summer rainfall is usually abundant and

grains and hay do exceptionally well. Sheep raising is quite important in the towns of Alden and Black Brook. Dairying is now the leading industry and will probably increase in importance in the future. Clover, timothy, and alfalfa do exceptionally well for hay crops.

In portions of southeast Polk county hay is sold at present in large quantities from the farms. It is usually baled directly from the field or from stacks later in the season. This system of selling hay from the farm is not altogether commendable unless concentrated feed for stock is imported. The better way is to adapt the farm practice so that the hay and forage crops are fed directly on the farm and the dairy product and live stock sold. This system of farm management of course, would require more work and skill, but on the other hand, the fertility of the soil could be maintained and increased by the application of manure from the stock, and the value of the farms increased.

The distance from market should also be considered in adopting systems of farming. Long hauls over heavy roads has the tendency to reduce farm produce to as concentrated a form as possible. For this reason, many farmers' co-operative creameries have been established. In southern Polk fewer creameries have been organized than cheese factories.

Oats are the most important grain crop and the average yield is 35 to 45 bushels per acre. Wheat is grown quite extensively, the yield on the heavier loams with high content of limestone being 18 to 20 bushels per acre, while on the lighter sandy loams the average yield is about 15 bushels. Barley on the heavier limesstone soil generally yields about 30 to 35 bushels per acre, and on the lighter sandy soil from 25 to 30 bushels. The corn crop is about as abundant as wheat or barley, the usual yields being from 30 to 35 bushels per acre. In Farmington and Osceola considerable corn is grown for silage. The potato is also an important crop, the usual yield being about 100 bushels per acre. The yield of hay is about one and one-half tons per acre.

Land Values.—The area of this soil is fairly well settled and a relatively large proportion of the land, probably 25 to 35 per cent, is under cultivation. Uncleared land is generally held at $15 to $25 per acre, and cleared land at $50 to $80 per acre. Quite often, however, farms well located and in a high state of cultivation are sold for more than $80 per acre.

RICE LAKE LOAM.

Area.—The Rice Lake loams are in bodies varying from five square miles to twenty square miles in extent, and are located in nearly all the counties of this area. The largest continuous tracts occur in the vicinity of Rice Lake and Barron in Barron county, and about Rusk in Dunn county. Another large area is in southwestern St. Croix county. East of Hudson this soil area is known as Hudson Prairie, north of Richmond as Star Prairie, near Chippewa Falls as Eagle Prairie and west of Eau Claire as Truax Prairie. Other small areas occur as indicated on the map. The total area includes about 328,000 acres.

Surface.—The soil is confined to the valleys, and is typical valley bottom land. The surface of this formation is uniformly level, with some portions quite flat. See Fig. 1, Plate X. Here and there small depressions may be found, some of which are occupied by small lakes. Some marshes and wet land are associated with this type, but the marshes are usually small and are not indicated on the map.

Forest.—In the area about Rice Lake in Barron county and about Eagleton in Chippewa county there was a rather dense growth of mixed hardwoods and pine. The hardwoods were mainly maple, oak, elm, and some basswood. Besides the white pine, there was some Norway pine and hemlock.

Farther west in Dunn and St. Croix counties, the native vegetation consisted largely of a light stand of scrub oak poplar, some birch and pine. In most cases the clearing of this thinly forested land was a comparatively easy matter for the early settlers.

Soil.—The Rice Lake loams vary from a fine sandy loam and loam to silt loam. Most of the soil, however, is a fine sandy loam or loam, and only in a small proportion of the area is silt loam. See Fig. 2, Plate X.

In general the surface eight inches is a loam carrying sufficient organic matter to produce a medium dark color. The subsoil is a sandy to silty loam to a depth of 1 to 3 feet, grading into gravel and sand. In places the gravel and sand subsoil lies very near the surface, less than a foot of loam overlying it. The surface soil also shows some variations, and grades from dark sandy loam to a brown, silty loam.

Fig. 1. TOBACCO FIELD ON RICE LAKE LOAM, EAGLE PRAIRIE, CHIPPEWA COUNTY.

Fig. 2. SECTION OF RICE LAKE LOAM, NEAR CAMPIA, BARRON COUNTY. TYPE OF ALLUVIAL SOIL.

This soil about Rice Lake and Barron, in Barron county, and in the area about Eagleton and Bloomer in Chippewa county, contains small areas of the heavier silt loam, but much the larger proportion in these localities is a fine sandy loam or loam. In eastern Eau Claire county in the valleys of Thompson's Creek, and Bear Grass Creek, silt loams predominate while in the valleys farther west fine sandy loams are the prevailing type. Silt loams also predominate in the small valleys on the west side of the Eau Galle river in the town of Eau Galle and Weston in Dunn county. Outside of the localities referred to, the soil mapped as this type is a fine sandy loam or loam.

The results of the mechanical analyses of the soil and subsoil are shown in the following table:

TABLE XVII.—*Mechanical analysis of Rice Lake loams.*

No.	Locality.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
6	Chippewa Co.....	Soil.....	.2	12.5	11.4	9.1	7.2	46.8	12.4
6	Chippewa Co.....	Subsoil...	.3	11.3	11.9	10.4	5.7	47.1	13.2
108	Dunn Co.....	Soil.....	.4	18.0	14.3	10.0	9.6	32.3	14.8
108	Dunn Co.....	Subsoil...	.4	11.9	14.3	12.1	16.4	29.8	15.1
124	St. Croix Co.....	Soil.....	.3	11.9	9.8	9.0	13.9	35.2	19.3
124	St. Croix Co.....	Subsoil...	.0	11.5	9.6	8.9	18.9	33.5	17.3
155	Barron Co.....	Soil.....	.3	20.6	14.9	9.1	4.0	36.3	14.2
155	Barron Co.....	Subsoil...	.2	20.1	14.7	11.3	8.8	28.7	15.4
157	Eau Claire Co....	Soil.....	.2	3.5	6.5	8.1	10.5	59.2	11.9
157	Eau Claire Co....	Subsoil...	.0	2.4	4.3	5.4	10.1	64.0	13.8

This soil is uniformly free from boulders, and practically all of it can be brought under cultivation. It is very largely under improvement in many of the areas. The dark sandy loams like that of Rusk Prairie and Hudson Prairie were easily brought under the plow and have long been under cultivation. The heavier phases of the soil do not contain a very high percentage of clay and are not sticky when wet and do not bake when dry. Where the land is nearly level some complaint is made on new land that the soil is cold in the spring, but this difficulty will probably be overcome after the land is cultivated more and the soil more thoroughly aerated. Some of the level tracts, however, will probably require tile drainage to bring them up to a proper state of fertility.

Chemical analyses of composite samples of the surface eight inches of the soil show it to be well supplied with potassium, with

a fair amount of nitrogen, and with a fair amount of phosphorus.

Extreme acidity has developed on much of this soil in Dunn and St. Croix counties. From a large number of actual fertilizer tests of acid soils, it has been shown that soils in an acid condition require phosphate fertilizer to insure best results. The Wisconsin Experiment station carried on considerable experimental work with acid soils, and results are published in Bulletin No. 139, showing quite conclusively that corn growing in acid soils made more rapid growth and developed more fully when a fartilizer was added which contained phosphorus, either alone or in combination with potash or nitrogen, than when phosphate was omitted and the potash and nitrogen alone were added either singly or in combinations. The supply of nitrogen can be maintained by judicious seeding of clover and alfalfa crops. At the present time but little of the latter valuable legume is being raised. Red clover does well as a rule.

In a dairy country, where bran or other concentrated food stuffs are commonly purchased, and where the manure is carefully cared for and little loss incurred from barnyard leaching and in handling, the supply of phosphorus can be maintained. This has been found true in older dairy sections of the state. Where the purchase of feed stuffs is impracticable, the phosphorus supply can be increased for large crops by the purchase of this element in the form of commercial fertilizers, as explained elsewhere.

Agriculture.—This soil has developed into one of the best general farming soils of the region. The common grains are all grown to a variable extent with good average returns. In the western part of the region in Dunn, Polk, and St. Croix counties on the thinly forested or prairie tracts, this soil was cropped to grain, especially wheat, for many years. The grain yields, however, after a few years decreased, and 20 to 30 bushels of wheat per acre became the exception instead of the rule. The causes that led to the decrease in yield were partly due to soil condition, and partly to the chinch bug. The result was that other grains, such as barley, rye, oats, and corn were tried and a rotation practiced. Clover became a crop that occupied the land a portion of the time. Stock raising became more general, especially for dairy purposes and during the last 15 years a marked

increase in dairy and live stock production has taken place. The census statistics show the increase in dairy products to have been very marked, during the last ten years through all the countries. On the whole this is a very desirable change as far as it concerns the maintenance of a good state of agriculture on this soil.

The present yield of wheat is about 12 to 18 bushels per acre, of oats 35 to 40 bushels, rye 12 to 15 bushels, of barley 30 to 35 bushels, and corn 25 to 35 bushels. The potato is usually an important crop, the avearge yield being 100 to 150 bushels per acre.

Special crops have developed to considerable extent north and northwest of River Falls, on the area northwest of Eau Claire known as Truax Prairie, and north of Chippewa on Eagle Prairie. The special crops are potatoes, tobacco, cabbage, canning peas, sweet corn, sugar beets, and small fruit. Peas for canning are extensively grown on this soil about Rice Lake, Campia, and Barron. An attractive market near by and soil adapted to such crops are doing much to increase the revenues from farming.

Where these special cultivated crops are grown to a large extent year after year, the rotation must include some crop that will replenish the organic matter which is removed by a system of special crops. Red clover or rye are excellent crops to plow down and allow to decay. The clover also serves the purpose of enriching the soil in nitrogen, one of the elements that special crops like peas and corn require in large amounts. The pea crop, although a leguminous crop, contributes but a small amount of nitrogen to the soil, its root system being very limited as compared to that of clover.

The location of these tracts near to towns of considerable size makes it possible to purchase manure from livery stables and elsewhere. Where this can be purchased at reasonable price it makes good fertilizing material although there is danger that fields so fertilized will become infested with noxious weeds. The system of farming, where such crops as peas are raised, is especially conducive to a rapid spread of weeds even where no manure from cities is applied. This is an added reason why rotation is desirable, involving clover and oats where these can be fed profitably to stock, either to sheep or to dairy cattle.

This probably is the preferable method of maintaining soil fertility on these areas, where special crops are remunerative and adapted to the soil condition. Corn is grown extensively in the Farmington area and to some extent in other portions of Polk county. In Barron county corn has not been grown so extensively on this soil.

Fertilizer requirements become of much importance in some of these special crop areas. Tobacco, cabbage, and potatoes and sugar beets are heavy feeders of potassium and where these crops are raised in considerable quantities, fertilizers rich in potassium are needed. Potassium sulphate at the rate of 150 to 175 pounds per acre will be sufficient for the special crops grown. The better and more economical way for the farmer is to purchase fertilizers for his particular crop requirement rather than to buy the complete fertilizer already mixed by the manufacturer, as the latter fertilizer often contains elements with which the soil is already well supplied.

While all grains receive more or less attention, the dairy industry is rapidly becoming much more important than grain raising; and while some grain is sold from the farm, the leading exports are dairy products and live stock. On most of this soil, the dairy product is cream sent to the local creamery. Farmers usually separate the milk on the farm. In Farmington, the cheese factories make American cheese, while in Rice Lake and Turtle Lake, the manufacture of brick cheese is more important.

Land Values.—Farm values on this soil are relatively high, the soil in general being well adapted to agriculture. Wild land is probably held at $20 to $30 per acre. Improved lands are sold at $50 to $100 per acre, the average prices being from $70 to $90 per acre. Well organized dairy farms, and farms devoted partly to special crops, especially to peas, command the highest prices.

CHETEK SANDY LOAM.

Area.—The Chetek sandy loam is in irregular areas bordering some of the large rivers and streams. It occurs in small tracts in every county except Rusk and Polk, the largest tract being in Barron county. In the entire area it includes about 230,000 acres. As a general rule this soil is associated with

VIEW OF CHETEK SANDY LOAM, NEAR ANSON, CHIPPEWA COUNTY.
Farm buildings and small groves of jack pine in the distance.

areas of the Sterling sand. Along the Red Ceder river in Barron county the close association of these two soils is well illustrated.

Surface.—The surface of this soil formation is nearly level, similar to that of the Sterling sand; but the surface is not quite so level in general as that of the latter, more areas within this type being somewhat slightly rolling. See Plate XI. In a few places around Cameron and east of Chetek, the soil is somewhat stony.

Native Forest.—The forest growth was mainly Jack pine with some white and black oak. As a rule the stand of timber was fairly dense.

Soil.—The Chetek sandy loam is a medium sandy loam to depth of eight inches. The surface soil contains considerable coarse and medium sand and is fairly well supplied with organic matter, giving it a medium dark color. The subsoil contains less organic matter and more coarse sand and gravel material than the surface soil as a rule.

The results of the mechanical analyses of this soil and subsoil from Barron and Chippewa counties are shown in the following table:

Mechanical analyses of Chetek sandy loam.

No.	Locality.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
160	Barron Co.....	Soil.....	.1	25.5	23.6	16.5	2.0	22.6	9.1
160	Barron Co.....	Subsoil...	.2	25.4	24.2	18.7	2.8	18.5	9.6
10	Chippewa Co.....	Soil...	.2	28.1	22.0	14.6	2.9	21.2	11.0
10	Chippewa Co.....	Subsoil...	.4	20.7	23.4	16.8	2.6	28.7	7.4

Around Cameron and east of Chetek, small boulders are associated with the surface soil but not in sufficient number to interfere with cultivation. Around River Falls, in Pierce county, this type shows variations, to a sandy loam and to muck. These heavier soil bodies are usually too small to be separated on the general soil map. Some of this soil in the bottom lands is only a few feet deep to the bed rock.

Agriculture.—The principal crops grown on this soil are oats, rye, corn, potatoes, and hay. Corn can be relied upon to ripen on this soil in Barron county as it permits planting earlier in

the spring than the heavier upland soils. The yield of oats is 25 to 35 bushels per acre, of corn 20 to 30 bushels. Potatoes are an important crop on this soil about Cameron and Chetek, the average yield being 100 to 150 bushels per acre. The yield of hay is generally from 1 to 1½ tons per acre.

The soil is well adapted to combination farming in which livestock and dairying should be most important. In order to maintain the fertility of sand or sandy loam soil, the keeping of abundant stock on the farms is of more importance than on the heavier soils. Manure, if sufficient amounts can be obtained, has always been the best fertilizer for the farmer. Besides supplying fertilizing material, it improves the physical condition of the soil as no commercial fertilizer can. Where manure cannot be purchased from outside sources, the farmer should arrange his system of farming so as to include dairy cows and such other live stock as is best adapted to his farming conditions. If this is not feasible, commercial fertilizer may be needed.

Clover has been grown on this soil with good success, and ought to be a more general crop. This soil is quite acid or "sour" as a rule and may require application of ground limestone where difficulty is experiences in obtaining a catch of clover. (See pages 71–2.) Alfalfa will do well when once a stand is obtained. These leguminous crops should occupy the land one to two years during the four year rotation period. The supply of total nitrogen in this soil, similar to that of nearly every sandy soil, is below the average. The growing of clover is the cheapest method for the farmer to replenish his soil with this valuable plant food constituent.

Special crops, such as tobacco, cucumbers, sweet corn, and peas are being grown, successfully, on limited areas of this soil about Chetek and Chippewa Falls. Where good markets are conveniently located, this soil ought to pay well, for it is an excellent truck soil.

Land Values.—Most of the soil of this type has been divided up into farms for a number of years. Uncleared land is generally held at $10 to $20 per acre. Improved land in a fair state of cultivation is generally held at $30 to $60 per acre. The farms devoted to dairying and to the special crops, peas, corn, or tobacco, command the highest prices.

MERIDEAN SANDY LOAM.

Area.—This soil mainly occupies the bottom lands lying along the lower Chippewa, Red Cedar, and Eau Galle rivers. The width of this bottom land varies from a narrow strip to a belt 1 mile to 2 miles wide. This soil is the lowest river bottom land and is about five to fifteen feet above the level of the river.

Surface.—The surface of this type is nearly level. Here and there are small undulating tracts. The shifting of the Chippewa river in places has cut off portions of its former river bed, thus forming small ponds in the abandoned river channel. Where marshes are found these are generally associated with cut-offs formed in this way.

Forest.—Practically all the forest growth has been removed from this soil. In scattered areas only are stands of elm, maple, ash and a few oak remaining. On the most sandy phases of this soil scrub oak and some pine were developed.

Soil.—The soil on these lower bottoms is usually sandy loam though it varies considerably. The surface eight inches contains considerable coarse and fine sand with small amount of clay material. The subsoil becomes sandier with more coarse and gravelly material. As a rule the surface soil carries a fair amount of organic matter and has a rather dark color.

While a large proportion of the river bottoms are light sandy loams, there are important areas of limited extent of heavier soil that differ markedly from the light sandy loam described above. This heavier soil is located along the Chippewa river in Dunn county in the vicinity of Caryville and Meridean, forming an area of about 15 to 20 square miles in all. Farther up the river in Eau Claire county in Secs. 4, 5, 8, 9, T. 26, R. 10, is another small tract. The surface eight inches on these more fertile areas is a fine sandy loam with some clayey material and high organic matter as evidenced by the dark color. The subsoil, eight to twenty-four inches, is made up of sandy soil lighter in color but also carrying a fairly high content of organic matter.

The results of the mechanical analyses of the heavier loam soil and subsoil are shown in the following table:

TABLE XVIII.—*Mechanical analyses of Meridean sandy loam.*

No.	Locality.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
11	Eau Claire Co....	Soil.....	.5	18.2	23.7	24.4	9.6	13.7	9.7
11	Eau Claire Co....	Subsoil...	.1	16.5	23.9	26.1	10.0	14.6	8.5
112	Dunn Co..... ...	Soil.....	.0	12.5	17.2	20.7	17.8	23.3	8.2
112	Dunn Co..... ..	Subsoil...	.2	12.6	16.8	21.9	19.9	20.5	8.1

Crops.—The heavier phase of Meridean sandy loam is being devoted to general farming including dairying and some grain raising, chiefly oats. Tame hay yields well, and corn is one of the best crops grown. At Meridean many silos have been built and the dairy interests supports a thriving creamery at this point.

The heavy phase of this soil in Eau Claire county is devoted to special crops and found to be very profitable. The leading special crops grown, are cabbage, sugar beets, sweet corn, potatoes, cucumbers, and tomatoes. The yields of these crops during 1909 seemed to warrant more extensive development. The question of the best means of fertilizing is very important in connection with the raising of special crops. Stable manure from Eau Claire has been shipped in and used by farmers on this soil. This is the best all-around fertilizer, but for certain crops, like cabbage and potatoes which require much potassium it will be more economical to buy this particular element in a commercial fertilizer. A commercial phosphate fertilizer also may be better than manure in some cases.

All the soil along the bottoms was found to be acid, indicating a general need of lime either as ground limestone or air-slaked lime. Clover can be raised on this type with good results and should be maintained in the rotation of crops.

On the sandy phase of this bottom soil mixed farming is conducted. The grains are mainly oats, rye, and some buckwheat. Potatoes and corn yield well. Some of this soil, however, is practically non-agricultural, due to the poor physical condition of the soil resulting from lack of drainage. For example a large part of the wet and marshy bottom land from Meridean to Durand on both sides of the Chippewa river is at present of little value agriculturally.

Land values.—The farm values along the river bottoms are quite variable. Most of this land is held at $25 to $50 per acre. However, farms on which dairying, stock-raising or truck raising are the leading features command prices from $50 to $100 per acre.

STERLING SAND.

Area.—The Sterling sand is typically developed in the central and western parts of the town of Sterling in northwestern Polk county. This locality is often referred to as "Sterling Prairie" because of its level surface and the general absence of forest trees.

This sandy soil area in the town of Sterling is a part of the large belt of so-called "barrens" or "plains" which is mainly confined to the vicinity of the St. Croix river and its tributaries, particularly the Nemakagon, Totogatig, Yellow, and Clam rivers. As outlined in a general way by Strong[1] this sandy plain is a linear tract having an average width of 12 to 15 miles, stretching from a point about 12 miles from the Bayfield peninsula nearly due southwest to the mouth of Wolf Creek in Polk county, a distance of 125 miles. This tract is joined by a tapering belt on the east lying along the Nemakagon river.

Besides the area of sandy soil in the town of Sterling, which is a part of the so-called "barrens" there are quite similar sandy soils within the area described in this report which may be conveniently classed with this type. The largest and most prominent of these areas is the large tract of sandy soil along the Eau Claire river in Eau Claire county. Other smaller areas, as indicated on the soil map, are along some of the small streams in southern Eau Claire county, and in eastern Pepin county. There is also a considerable area of this type north of the Chippewa river in the town of Spring Brook, Dunn county, and another along the Mississippi river in the vicinity of Pepin and Hager.

Surface.—The surface of this type of soil is uniformly nearly level. In many places, however, the nearly level surface is broken by the occurrence of ridges of wind blown sand, "sand dunes," and in other places by narrow valleys cut by streams and by small sags or depressions left by glacial action. In

[1] Geol. of Wis. Vol. III, p. 386.

places this type of soil is closey associated with marshes and wet sandy land.

Native Vegetation.—This type of soil was originally only sparsely covered with forest trees. Considerable areas were practically free from timber, while other areas were covered with a light growth of jack-pine, aspen, and occasionally Norway pine. Other areas were covered with burr oak, black oak, and white oak brush with occasional trees of these species. The common "brake" and "sweet fern" are usually present on this soil.

Groundwater Conditions.—The depth to the level of ground water in this sandy soil is variable. In the town of Sterling in northwestern Polk, the wells are generally from 20 to 40 feet deep. In eastern Eau Claire county the ground water level is generally quite near the surface, except immediately adjacent to the Eau Claire river. In many places in eastern Eau Claire the general water level is only from 10 to 15 feet below the surface and where this condition prevails the agricultural possibilities of the soil is enhanced. Along the Chippewa and Mississippi rivers the water level is generally from 40 to 80 feet below the surface.

The lack of forest growth on this soil is largely determined, very probably, by lack of moisture in the subsoil.

Soil.—The Sterling sand in its typical development consists mainly of medium sand somewhat brownish and dark at the surface, grading down to lighter colored sand. In places a gravelly subsoil is struck at depth of two or three feet, but generally the subsoil is medium to coarse sand to a considerable depth. The mechanical analyses of representative samples of this soil from various localities are shown in the following table:

TABLE XIX.—*Mechanical analyses of Sterling sand.*

No.	Locality.	Description.	Fine gravel	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
145	Polk Co., T. 36, R. 19.....	Soil.....	.0	5.9	22.4	46.5	15.7	4.9	4.2
145	Polk Co., T. 36, R. 19.....	Subsoil...	.3	7.2	26.5	46.2	12.5	3.7	3.7
15	Eau Claire Co., T. 26, R. 6.....	Soil.....	1.1	12.4	13.5	44.0	17.4	7.8	4.6
15	Eau Claire Co., T. 26, R. 6.....	Subsoil...	.0	17.1	14.1	43.1	18.1	4.3	3.3
108	Dunn Co., T. 27, R. 11.....	Soil.....	.3	20.8	24.8	33.6	5.7	7.0	6.9
108	Dunn Co., T. 27, R. 11.....	Subsoil...	.4	22.5	28.6	31.1	5.5	6.2	6.1
117	Pepin Co., T. 25, R. 13, 14.....	Soil.....	.7	15.4	27.7	34.5	9.2	7.8	5.0
117	Pepin Co., T. 25, R. 13, 14.....	Subsoil...	.6	14.2	24.9	37.3	9.0	7.3	6.0

The mechanical analyses of these samples from the several counties, are very similar to one another and are almost identical with the analysis of the Plainfield sand type of the U. S. Bureau of Soils classification. The Sterling sand is approximately the same type of soil as the Wisconsin river sandy soil described in the soil report of North Central Wisconsin.*

The nitrogen and organic matter in the Sterling sand are relatively low, the chemical analysis showing about one-half the amount of these constituents in this type as occur in the loams and silt loams of the area. There is, however, a considerable variation from place to place in the amount of organic matter. Some of this soil in Pepin county contains considerable dark organic material in the surface three or four inches of soil. On the other hand along the Eau Claire river in eastern Eau Claire county there is a large area characterized by its nearly white color, indicative of only a small amount of organic material in the surface soil.

From the limited number of chemical analyses which have been made thus far it appears that these sandy soils are fairly well supplied with potassium while the supply of phosphorus is considerably less than in loam soils.

Besides the smaller amounts of plant food in the sandy soils, which in many cases is in forms not available to plants, the lower grade of fertility of the soil type is due to the porous

* Bull. 11 Wis. Survey, p. 17–20.

texture of the soil, causing excessive leaching of soluble plant food, and to its incapacity to retain sufficient soil moisture for crop use during critical stages of plant growth.

The Sterling sand, not alone along the Eau Claire river and along other rivers of the southern part of the area but also in the town of Sterling and the associated tract of "sand plains" or "barrens" of the upper St. Croix river and tributaries is a typical alluvial sand formation deposited by rivers.

Red lacustrine clays were observed along the St. Croix river just north of Nevers' dam, and at the mouth of Wolf Creek. In the continuation of the Sterling sand belt in Burnett county red lacustrine clays were observed about Grantsburg beneath the sand formation. Similar red calcarecus lacustrine clays were observed in some of the valleys of Eau Claire county. These lacustrine clays are essentially similar in character and origin to the red clays along Lake Michigan and Lake Superior, although these interior deposits are likely to contain a larger proportion of sand and silt than the clays occurring adjacent to the Great Lakes.

Wherever these lacustrine red clays are associated with the sands and come near enough to the surface to contribute material to the surface soils and influence soil moisture phases of loams are developed having a higher grade of fertility than the uniformly deep sand soils.

Agriculture.—This sandy alluvial soil, on account of its open porous character is subject to leaching of soluble plant food, and the rapid oxidation of organic matter. As a type it is probably the most infertile soil of the state. It is the only soil within this area in which abandoned farms have been observed. However, this soil type in other parts of the state and also within this area is being farmed with fair yields of crops under proper management.

The principal grain crops grown on this soil are oats, rye, and corn. The yield per acre is variable depending entirely on proper management of the soil. Where the state of fertility of the soil is maintained nearly as good average yields are obtained as on the loam soils. Special crops, such as sweet corn, potatoes, and beans are well adopted to this soil type. The potato is an especially good crop, and yields of 100 to 150 bushels per acre are common. The bean is quite extensively grown on this

type of soil in certain parts of Michigan and the acreage of this crop should be increased in this region.

Dairying may be carried on profitably in conjunction with the special and grain crops mentioned above. Where dairying is practised the principal forage crops are clover and corn, the latter often used as silage. Alfalfa can also be grown on this soil under proper soil conditions.

Land Values.—The land values on this soil type are quite variable, depending largely on the conditions under which the farms are managed. Wild land is generally held at $5 to $10 per acre. Land under cultivation is generally held at $10 to $30 per acre with some farms under the very best management often selling above $30 per acre.

Management of Sandy Soils.—The management* of sandy soils presents some of the most difficult problems confronting the farmer today and it is doubtful whether some of the abandoned farms on this soil will be reclaimed until the difference in cost of more productive soils of the state is greater than it is at present. Just as soon as the heavier loam soils are all taken, and values reach $100 or more per acre, the light sandy soils will be again brought under cultivation and made to produce such crops as are adapted to sandy soils. This is the condition at present in the older parts of this state and also abroad where large tracts of abandoned lands of sandy nature have been made productive under proper management.

As already stated sandy soils are difficult to manage. In a fertilizer test on this soil a complete fertilizer produces the best results. Potash, however, in sufficient amounts is usually found in this area as shown by chemical analyses.

The first step in the improvement of sandy soil is to increase the organic matter. Besides supplying nitrogen the water-holding capacity of the soil is increased by incorporation of vegetable matter. For this purpose clover is the best crop that the farmer can grow. This introduces a difficulty at once, for, as many farmers can well testify, to secure a catch is not an easy matter. Sandy soils are quite generally acid, and it has been found that clover prefers non-acid soils. Again, the season may be too dry or the soil may be exhausted by long pre-

* For a more complete discussion of the improvement of sandy soils, see Bulletin 204, Wis. Exp. Station, Madison, Wis.

vious cropping, so that an application of barnyard manure or commercial fertilizer is needed to give the young clover plant a start until it can appropriate nitrogen from the air. Where soil shows acidity, an application of ground limestone at the rate of one ton per acre will be found beneficial. Air-slacked lime, marl or lime refuse from sugar beet factories are equally efficient.

This ground limestone may be added after the field is ready for planting, seeding to oats or rye being preferable, at the rate of six pecks per acre, and seeded with mammoth clover at the rate of 10 quarts per acre. If manure can be obtained it would help greatly to insure a stand if applied before seeding to grain at the rate of about four loads per acre. Should the season come off dry, it may be advisable to cut the grain green for hay in order to afford better moisture conditions for the clover seeding.

If a stand is obtained, the first crop may be cut for hay and second crop either be plowed under or allowed to go to seed. If this second crop is plowed under an application of 1000 pounds of ground rock phosphate per acre should be made. After the clover should follow a cultivated crop of corn or potatoes. This cultivated crop is followed by grain again and seeded with clover as before.

If conditions warrant the clover may be allowed to stand until the second year before being plowed under, thus making a four year rotation. At the beginning of this building up process, the three year rotation will perhaps be preferable.

After this heavy phosphate application, the amount added may be reduced and about one-fourth as much added once during a four year period. This system has been found successful by the State Experiment Station on sandy soils similar to this type. Farmers should not expect too much at the start, especially if the soil has been cropped continuously for many years and little manure added.

These soils are well adapted to clovers, and alfalfa will also thrive. Some fine fields of red clover were observed on the light sandy soil along the Red Cedar river in Dunn county. The clover was grown for seed in this section and was one of the principal sources of income from the farms. Dairying was carried on in connection, and manure, applied systematically. The land in the area was cropped to grains and other crops about

VIEW OF HARTLAND SILT LOAM, NEAR ELLSWORTH, PIERCE COUNTY.
A characteristic view of the loess-covered uplands over the limestone.

one-half the time, the remainder of the time given over to clover and pasture. It is needless to say that abandoned farms were not conspicuous in this locality.

An experimental farm on light sandy soil at Spooner, Washburn county, was recently started by the State Experimental Station. An experimental farm on similar sand in Marinette county also has recently been organized. Practical results in the management of sandy soil will be worked out and reported as early as possible.

HARTLAND SILT LOAM (LOESS).

Area.—The Hartland silt loam is principally in Pierce, Pepin and Dunn counties. The largest continuous area of this soil type forms a broad tract including nearly three-fourths of Pierce, more than one-half of Pepin and a long belt extending northward through the western townships of Dunn county. In Chippewa county there is an area of over a township located in Tilden, northwest of Chippewa Falls. There is a small area of the loess soil type about Ludington in Eau Claire county. South of a line between Augusta and Fall Creek is the most extensive tract in Eau Claire county, embracing about two townships. The total area of this soil is about 556,000 acres.

Surface Features.—The surface features of this formation are rolling or undulating, to hilly. See Plate XII. The surface inequalities are due chiefly to erosion of the underlying rock and the topography is often spoken of as an erosion or stream topography. No uniformity exists over any large area. For example adjacent to rivers or intermittent streams are areas ranging in width from one-half to three-fourths of a mile, which are likely to include considerable land that is rough and broken. This is especially the condition where the main rivers have eroded deep beds as is the case with most of the streams in Pierce and Pepin counties. Most of these deep channeled streams have developed extensive systems of short tributaries, nearly at right angles to the main stream and leading abruptly up to the adjacent uplands. These tributaries or feeders are dry runs except during rains or melting of the snow. In Chippewa and Eau Claire counties the streams channels are not as deep as those in Pierce, Pepin, and parts of Dunn, and consequently fewer of the extremely undulating areas are found.

Forests—Over a broad belt reaching from the vicinity of Prescott and extending along the south border of Pierce and Pepin an area of hard woods, mainly of oak was originally developed. The stand was usually light and was referred to as "burr oak openings" by early settlers. At present no forest area of any extent remains on this tract except on the slopes or bottom lands. Similar forests of oak grew over the area northwest of Chippewa Falls, and in southeast Eau Claire county. In the remaining areas mixed hardwoods consisting of maple, oak, elm, and bass wood developed. Considerable pine and hemlock was associated with the hardwoods in southwest Dunn county and in eastern Chippewa county.

At the present time the timber products of this soil area are of little importance as compared with the agricultural products. In the town of Weston, Dunn county, there is a tract of 7500 acres of hardwood forest and a large saw mill is operated in that locality.

Soil.—The soil is a silt loam of medium dark buff color to a depth of six to eight inches. It is remarkably free from pebbles or stone, and possesses a characteristic smooth powdery feel. The mechanical analyses show that this soil is made up very largely of silt (grains whose diameters range between .05 to .005 mm); the clay content is usually low. The mechanical condition of the soil affects its physical properties profoundly. It can withstand heavy rainfall better than the heavier compact clay soils and does not bake or pack after rains.

The soil on account of its porous nature is subject to leaching of its soluble plant food. On similar soils in Iowa large tracts were rendered infertile on account of the rapid decomposition of its organic matter, but as yet there appears no danger from this source here. Chemical analyses show an average high content of organic matter. The subsoil, below eight inches, is buff to yellow in color and remarkably uniform in structure. The clay content is somewhat higher in the subsoil than in the surface soil. Like the surface soil the subsoil contains no coarse material.

The depth of the loess subsoil varies in the different areas. In Pierce and Pepin county the average depth is six to eight feet with some upland tracts much deeper. In eastern Chippewa this soil does not show the same degree of uniformity found in

Fig. 1. SECTION OF AUBURN LOAM.
Type of residual soil on shaly sandstone. Near Menomonie, Dunn County.

Fig. 2. SECTION OF HARTLAND SILT LOAM.
Shows two to four feet of loess overlying shaly sandstone. On upland southeast of Chippewa Falls.

the other areas. As a rule it is not as deep either. This soil in Pierce, Pepin and western Dunn counties is generally underlain by limestone, and in the other counties by sandstone. The relation of the loess soil to the underlying sandstone is illustrated in fig. 2, Plate XIII.

The results of the mechanical analyses of the soil and subsoil are shown in the following table:

TABLE XX.—*Mechanical analyses of Hartland silt loam* (Loess).

No.	Locality.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
116	Pepin Co.	Soil	.0	.9	.7	3.3	18.7	65.1	11.5
118	Pepin Co.	Subsoil	.0	.2	.3	2.1	27.8	56.5	13.0
9	Chippewa Co.	Soil	.1	1.3	1.4	2.2	22.1	62.1	10.1
9	Chippewa Co.	Subsoil	.0	.1	.2	.5	7.3	78.7	12.9
113	Dunn Co.	Soil	.4	1.6	1.4	7.2	27.5	51.8	9.9
113	Dunn Co.	Subsoil	.0	.6	.5	2.0	32.1	53.9	10.4

The origin of this silty loam explains in a measure its uniformity. This soil is "loess," and was deposited by wind carrying fine material from unprotected areas farther west. The loess soils are widespread over large portions of the Mississippi valley.

On account of the uniform silty composition of this soil type and its rolling character it is particularly susceptible to side hill erosion. The loss from this source may be considerable, depending on the slope and the kind of crop raised. Usually where ordinary care is taken destructive gullying can be prevented, although many areas were observed that were badly cut up into large and small ditches.

In general when the slope is steep it should remain in hay or meadow land most of the time, only plowing it up in order to reseed again. The crops raised also influence the liability of erosion. Areas planted to potatoes and corn are subject to most erosion. The best system to follow in farming the slopes is to crop with oats, wheat or barley, in rotation with clover. The slopes should remain in hay or meadow about two years out of a four or five year rotation—preferably two years out of four. Keeping the runways of water in sod has worked fairly satisfactory in some cases. On sloping clay soil in the southern states, furrows dug along at right angles to slope "terracing" have been found an efficient and cheap means of lessening slope

erosion. These furrows are placed at intervals of about 100 feet and connect with an outlet ditch down the slope at one end of the field. The system so constructed is maintained permanently though it offers some inconvenience in the use of farm machinery.

Tiling similar uplands has been found advantageous, in reducing the loss from erosion. In sloping soils tile laid in the direction of slope six to eight rods apart increased the water holdng capacity and decreased the surface run-off very materially.

Agriculture.—This soil type is especially well adapted to grain raising and to general farming in which dairy products are the important exports from the farm. Both these systems are being carried on on this soil type. Grain raising is confined principally to the so-called "prairie" tracts, the largest area of which extends along the southern border of Pierce and in Pepin counties. The grains raised are mainly oats and barley; less wheat is raised now than 15 years ago when this section was well known as a wheat growing area.

The areas originally forested with hardwoods have adopted combination farming, and here dairy products are in the lead. The grains, oats, barley and corn are raised and yield well, but do not form an appreciable portion of the exports.

These two systems of farming differ radically in their influence on keeping up the fertility of the soil. The grain farmer in the past has not concerned himself very much with principles of soil fertility, not alone in this area but in all grain raising sections of the country. Up to about 1890 the grain section of this soil type was devoted to wheat. No attempt at rotation was made and clover was grown in only limited areas. A shrinkage in yield and partial loss of crops in the early nineties resulted in less wheat being grown, and brought about a rotation involving the growing of a variety of grains such as oats, barley and some wheat. Clover also was more generally grown. This system is practiced now and the leading grains are oats and barley; more live stock is being kept and the stock furnishes needed fertilizer. Farmers, however, depend largely on clovers to enrich their soils and as a proof of increased fertility point to the fine yields now obtained. While clover is important, it adds but one of the plant food elements essential to crops, namely the element

VIEW OF HARTLAND SILT LOAM, NEAR MENOMONIE, DUNN COUNTY.
Shows an area of very thin loess over the shaly sandstone.

nitrogen. Besides supplying nitrogen, however, the clover also adds organic matter to the soil, and also improves the physical condition of the soil by its deep root system, permitting air and water to enter the soil more thoroughly.

But while clover adds nitrogen and organic material to the soil, it removes large amounts of phosphorus like the grain crops. Barn yard manure, where it is available, adds phosphorus as well as nitrogen to the soil. But even where the manure is obtained from forage and grain crops grown on the farm, the supply of phosphorus is not increased but rather decreased due to the loss by leaching and otherwise in handling the manure.

The grain farmer may, therefore, find it advisable to apply phosphorus to the soil which has been subjected to excessive or continuous cropping. The cheapest form in which to supply phosphorus is by application of the ground rock phosphate as explained in another place. An application of 800 to 1000 pounds per acre to begin with and a light application of about 250 pounds per acre thereafter, during each rotation period will usually be sufficient. Clover should occupy the land two years during a four or five year rotation with oats, barley or wheat.

The farmer who practices combination farming, in which live stock, dairy cows, fat stock, hogs, and sheep are kept, usually sells no grain from the farm and in addition usually purchases concentrated feed stuffs, such as bran which is high in phosphorus content. The supply of nitrogen in the soil can be maintained by growing of leguminous crops, such as clover. Potassium is an abundant element in this soil type as the chemical analyses of a large number of soils indicates.

A larger acreage of this soil type in Pierce and Pepin is devoted to barley than to oats, barley being the leading grain in these two counties. In the other counties, the oats are the principal grain raised on this soil. In Pierce and Pepin the average yield of barley is 30 to 35 bushels per acre. In the other counties the yield is about 30 bushels, with the exception of the town of Lincoln in Eau Claire where 35 bushels is the average yield.

The average yield of wheat is 15 to 18 bushels per acre, and of oats about 40 bushels per acre. The acreage of rye in some localities is equal to that of wheat, with an average yield of 15 to 20 bushels per acre. The acreage of corn on this soil is less than that of barley or oats in Pierce and Pepin and less than

oats and more than barley in Dunn, Chippewa and Eau Claire. The yield of corn per acre is generally from 30 to 35 bushels. Clover and timothy are the main crops for forage. In a few areas alfalfa has been tried. This soil is admirably adapted to alfalfa, and it ought to be more generally grown.

Special Crops.—Similar silt loam soils have been found admirably adapted to fruit culture in other states. In this area considerable fruit is now being grown, especially apples and some plums. The hill sides where erosion is troublesome are well adapted to fruit trees and grape vines. The fruit culture ought to be encouraged and more care given to the trees by spraying and pruning when needed.

Land Values.—This type of soil is one of the most fertile in the entire region. Farm values therefore are relatively high, as they are elsewhere on the loess soils throughout the Mississippi Valley. With few exceptions this soil has been laid out in farms for many years. Uncleared land, with little or no merchantable timber, is generally held at $20 to $40 per acre. Cleared land is generally held at $60 to $100 per acre. Farms on which dairying is the principle industry, as in Cook's Valley, Chippewa county, command higher prices than farms which have been devoted mainly to grain raising.

AUBURN LOAM.

Area.—The Auburn loam lies in Chippewa, Eau Claire, Dunn and Barron counties. The soil of the town of Auburn, Chippewa county, is mainly of this type, hence the name. The boundaries of the various bodies are very irregular, as shown on the map. Many of these bodies are small, but often they are extensive, as for example the area southeast of Menomonie, in Dunn county, a tract nearly two townships in extent and the large area in northwestern Chippewa county and in southeastern Barron county. Around Elk Mound is another large area, and in Eau Claire county are also a number of areas of considerable extent.

Surface.—The Auburn loam is characterized by a hilly and undulating surface, becoming in places quite rough and the slopes quite steep. The topography is characteristic stream erosion topography developed on sandstone and shale formations. Not all the area is hilly and undulating. The surface is

VIEW OF AUBURN LOAM, SOUTHWEST OF EAU CLAIRE.
Shows the characteristic valleys and even uplands of this type of soil area.

more gently roling in the area south of Elk Mound. In other places similar uplands with gentle slopes are found but more often sharply undulating and hilly features prevail. The surface features are illustrated in Plates XIV and XV.

Forest.—The area was originally wooded with hardwoods, mainly red oak, black oak, burr oak, some birch, poplar and scattering maple. At present considerable wooded tracts remain made up chiefly of black oak, and poplar. More of the steeply sloping areas of this soil type ought to remain in forest These slope areas are well adapted to tree growth and when covered with forest would prevent destructive gullying so noticeable on many of the fields which lie on the slopes.

Soil.—The surface eight inches of this soil varies from a loam to a silt loam containing considerable silt. The surface soil is buff to yellowish in color and contains a medium amount of organic matter. The subsoil to depth of 24 inches is usually a sandy to clayey loam. At three to three and one-half feet the soil in many cases become quite sandy. Shale and sand rock outcrops are common along road cuts and in many places there are only a few inches of soil overlying the sandstone formation. The sandstone and overlying soil is illustrated in figure 1, Plate XIII.

The Auburn loam has been formed largely from the weathering of shaley sandstone of the Potsdam (Middle Cambrian) formation. The shale contains much coarse sand and a large proportion of clayey material. Although the area of this soil has been glaciated by the earliest glaciers, only a very small contribution of drift was added to the soil. The soil is a typical residual soil and is the only one of this class within the area. While the general soil type is a loam, there are considerable areas in which the soil becomes quite sandy. The more sandy soils are usually in the areas where the underlying rock is a nearly pure sandstone, without any shale and the soil is the direct result of weathered pure sandstone. North of Wheeler in Dunn county some especially sandy areas are found. Likewise in the eastern part of Eau Claire county there are isolated areas of very sandy uplands.

The results of the mechanical analyses of the soil and subsoil from various parts of the area are shown in the following table:

TABLE XXI.—*Mechanical analyses of the Auburn loam.*

No.	Locality.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
158	Barron Co.....	Soil.....	.1	3.3	5.9	11.6	9 6	57.1	11.9
158	Barron Co.....	Subsoil...	.0	4.1	6.4	15.3	15.4	39.8	19.0
12	Eau Claire Co..	Soil.....	.2	6.9	11.1	13.1	14.9	42.7	10.5
12	Eau Claire Co..	Subsoil...	.0	5.3	9.6	14.4	15.1	43.0	12.5
110	Dunn Co.....	Soil.....	.5	15.0	18.0	17.6	12.9	26.6	9.7
110	Dunn Co.....	Subsoil..	.5	14.3	17.3	19.0	18.9	21.1	9.3

Somewhat heavier soils as well as lighter, more sandy soils than those analyzed in the table occur within the area. But the variation in the general texture of the soil is fairly well illustrated by the samples analyzed.

Soil Erosion.—The character of this soil with regard to its topography affords conditions favorable to side hill erosion. It is difficult to estimate the annual loss by erosion, either from loss in fertility by removal of fine soil particles or in consequence of gullying of the fields where the slopes are cultivated. As above stated as far as possible the steep slopes should remain in forest. If the steep slopes are already cleared the cultivated crops should not be planted oftener than once in three or four years, and the slopes should be allowed to remain in hay meadows or pasture the remainder of the time. Farmers thus far have not apparently appreciated the loss from erosion, otherwise more precaution would have been exercised to prevent it.

Agriculture.—A highly developed system of diversified farming is practiced on this soil type. Abundant pasture lands and a soil well adapted to cereals and corn make this area one especialy well suited for general farming.

The usual grains are oats, barley, wheat and some rye. Oats, however, are the leading grain, the average yield being 35 bushels per acre. Corn is an important crop, especially in Dunn county. It matures early and yields 40 to 50 bushels per acre.

Clover and timothy are the usual hay crops, the average yield being one to two tons per acre. Alfalfa has not been introduced extensively as yet but where farmers have planted small fields it has been found to give splendid results. It will probably be more extensively grown on this soil when its value as a forage crop is realized. The potato crop is generally important on the sandy loam, the yields being 100 to 150 bushels per acre.

Dairy products together with live stock, hogs, beef, etc., are the leading exports from the farm. Cream is shipped to local creameries operated on a co-operative basis by the farmers. Very little grain is sold from the farm, but is fed on the farm and sold as manufactured dairy and live stock product. The tendency at present is toward keeping more pure-blooded animals, of dairy type as a rule; breeders' organizations are aiding materially in the movement to eliminate the scrub cow from the farm.

Besides the general system of farming to which this soil is well adapted, the production of fruit ought to receive more attention. The loamy soil is splendidly adapted for raising apples and other tree fruits. The steep hillsides may be brought to produce abundantly when planted to fruit trees and grapevines, provided proper attention be given. At the present time little has been attempted in this way. The Auburn loam, except where the very sandy phases predominate is one of the most productive soils of northwestern Wisconsin. Crop yields have been fairly well maintained and only few farms showed soil in poor condition. Acidity of the soil has not developed to a large extent.

The supply of nitrogen can be maintained by the growing of leguminous crops, clover and alfalfa. This is the cheapest source of obtaining the most expensive constituent of plant food. With regard to phosphorus farmers have already in few instances expended $4 to $4.50 per acre for rock phosphate fertilizer. Where concentrated food stuffs for stock is not brought onto the farm from outside sources the application of mineral phosphate is a good method of maintaining the soil with high phosphorus content.

Land Values.—Practically all this soil type is now laid out into farms though less than one-half is cleared land. Uncleared land is generally held at $15 to $30 per acre, and cleared land from $50 to $80, with occasional higher prices where farms are well situated and in a good state of improvement.

PEAT AND MUCK. (Marshland.)

Area.—While marshy tracts of more or less limited extent occur in all of the counties five of the counties contain a larger proportion of marsh than the others. These are Chippewa, Rusk,

Barron, Dunn and Eau Claire. In Chippewa and Rusk are areas occupying four to five thousand acres in one continuous marsh tract. In Barron, Dunn and Eau Claire counties many small areas adjacent to streams or in bottom lands are wet and marshy. In Polk many small tracts of marshy areas occur over the entire county.

Surface.—The surface of these marshes is nearly level, the level surface being primarily the cause of its being a marsh. But while the areas appear to have almost a level surface, upon more careful observation a fall, sufficient for drainage can usually be obtained.

Native Vegetation.—Over many marsh areas a stand of tamarack, some cedar, and willows are found, while in others only marsh grass thrives. Moss is a common growth acquiring a depth of several feet in some cases. The peat in the marshes consists of an accumulation of moss and marsh grass, and varies widely in depth. In Dunn and southern Chippewa and Eau Claire the depth ranges from two to four feet, and is underlain by sandy subsoil. Along the Lamb Creek in Dunn county four to five feet of peat were often measured before the sandy lower soil was reached. In Rusk county large areas where the peat measured about three feet before clay soil was reached were common.

Oftentimes lakes and ponds are included within marshy land, making it more difficult of drainage unless sufficient fall and outlet can be secured.

Of the marsh lands of the entire area, a conservative estimate would be about five to six per cent. In Pierce and St. Croix counties less than one per cent of the total area is marsh land. The amount of marsh land in some of the townships in eastern Rusk, and northeastern Chippewa where marsh and swamp land is most abundant is probably from 20 to 25 per cent of the township. Other townships in Rusk and Chippewa counties have less than one per cent of marsh land.

The agricultural value of these marsh areas is dependant entirely upon their reclamation. At the present time undrained and unimproved the larger proportion of marsh land is only of incidental value and then only for wild hay as a rule. In the management of these marshes the first requisite is proper drainage to remove surplus water and thus fit the area for cultivation.

Before taking up the question of crops and fertilizer requirement the subject of drainage will be discussed. The following discussion is abstracted from a recent bulletin* of the Wisconsin Experiment Station.

Drainage of Marsh Lands. *Deep outlet ditches.* The construction of deep outlet ditches is the first step in the reclamation of broad marsh areas, particularly the peat marshes. Such marshes usually receive the run-off from upland areas several times their size. Covered drains of the required capacity would be very expensive.

The minimum depth of outlet ditches should be five feet, except where opportunities for self cleaning are good, when the depth may be decreased to four feet. The bottom width should be at least one-half of the depth. Eight feet is perhaps the most advisable depth on marshes more than half a mile wide. On marshes less than half a mile wide or where the transverse slope to the ditch is more than a foot in eighty rods, the depth may be reduced. Here also the bottom width should be at least one-half the depth and as much more as the requirements seem to demand. It must be remembered that it is the depth to which a ditch will empty itself and not the depth to which it is dug that determines its efficiency.

Usually the outlet ditch is not made too deep, but it is often made too wide. One ditch that has been observed was made four feet deep and sixteen feet wide, because the dredge used could not make a narrower ditch. The result was that during the normal summer flow, a stream about two feet wide shifted from one side to the other on the wide bottom. The remainder of the bottom grew up with rank weeds, which, collecting sediment during high water, is gradually filling up the ditch. A ditch with a four foot bottom and six feet deep would be more serviceable and durable. Dredge men unskilled at handling the dipper frequently find it easier to make the slopes almost vertical. This should not be tolerated because with such slopes the banks are almost certain to fall in and to accumulate on the bottom of the ditch. A ditch six feet wide at the bottom, six feet deep and eighteen feet wide at the top (6x6x18) is more permanent than a ditch of the same depth and eighteen feet wide at

* "Principles and Practice of Land Drainage," by E. R. Jones, Bulletin No. 199, Wis. Exp. Station.

the bottom and top. With a small effort the slopes of the former ditch can be made smooth and sodded over to prevent erosion and growth of rank weeds.

Shallow Surface Ditches.—Shallow surface ditches are those intended only to conduct surface water to deep ditches or to natural outlets. Since they are of use only during flood flow, they are dry most of the time and they may be called "dry" ditches.

Forms and Size.—Except where a cutting has to be made through a ridge they seldom need to be more than two feet deep. With rounded bottoms and a top width of ten or twelve feet the slopes are such as to admit of crossing with teams, vehicles, and implements. Where the slopes and bottom are sodded, the appearance is improved and the grass growing in them may be mowed for hay. Shallow ditches along permanent fences, where they will be out of the way of cultivation may be made narrower and with steeper side slopes.

All that has been claimed for deep outlet ditches is that they are the first step in the reclamation of a humus marsh. They stand ready to carry off the water brought to them, but are slow to reach out after water. The logical way of developing a humus marsh is as follows: Co-operate with your neighbors in organizing a drainage district and put in a deep outlet ditch. Then along forty lines or property lines put in shallow surface ditches one foot deep at the head and perhaps three feet deep where they empty in the deep ditch. Then plow the adjacent fields in narrow lands so that there will be dead furrows every four rods leading into the shallow ditches. Such a net work of surface drains with a deep ditch for an outlet will afford sufficient drainage to raise timothy hay on the area. When it seems advisable to put in covered underdrains, other crops may be raised. Small ditches with dikes on the side toward the marsh are frequently used to protect marshes from flood water. The dike may be made of the earth excavated.

Cost.—The construction of the vast majority of deep outlet ditches requires the use of steam or gasoline dredges. The cost of hauling a dredge from the railroad station to the marsh, and that of putting it together and tearing it apart is the same whether the ditch be long or short. Large contracts are frequently taken for seven cents a cubic yard. The rate for small

contracts is sometimes twice that figure. At ten cents a yard a 6x7x20 ditch costs about $1,700 a mile. Peat can be handled for less money than either sand or clay.

The cost of shallow ditches can be materially decreased if a dry time is chosen for their construction. Where team and scraper or a road grader can be used, a depression two feet deep and ten or twelve feet wide at the top can be made for thirty cents a rod.

Causes of Failure.—It is evident, that three of the causes of failure in the reclamation of humus marshes are: (1) shallow ditches have been put in without first providing a deep ditch for an outlet; (2) deep ditches have been put in without afterwards putting in shallow ditches for feeders; and (3) some well drained marshes have been poorly managed.

Deep and shallow ditches should be given an opportunity to work hand in hand. Neither is complete without the other. Land owners who have expended five dollars an acre for a deep outlet ditch, lose a large part of its value by refusing to expend two dollars an acre more upon surface ditches for feeders, or a greater amount for tile where deeper and more permanent drainage is desired.

Crops.—Having properly provided for removal of surplus water by suitable drainage system as outlined above, the question of crops adapted and fertilizer requirement is in order. It may be stated at the outset that the marsh tracts of this section differ in some respects from similar tracts in adjoining states. Some of the peat here is not so well decomposed—not so muck-like,—and not so deep as those of neighboring states. The crops to which Wisconsin marshes are adapted likewise differ. Of course the location being further north, likewise exerts an influence on plant growth not always given due weight.

The best crop thus far tried on Wisconsin marshes for the first year or two is buckwheat. The marsh is plowed to a depth of 6 inches or so and disked up and seeded to buckwheat at a rate of 1 bushel per acre. After first or second crop of buckwheat the field may be seeded to alsike and timothy or red top and if a system of farming is followed that requires much hay the marsh land can very profitably be devoted to that purpose. It will, of course, be necessary occasionally to turn up the sod and seed to some grain crop to establish new growth of seeding

again. Yields of two tons of hay per acre are not uncommon when this type of land has been properly managed and cared for.

If grain crops are desirable, barley has been found preferable, and also corn where climate is favorable. Oats was found to do wonderfully well in some areas. Trucking crops, such as potatoes and cabbage, have proved successfull as well.

To maintain maximum yields addition of fertilizing material is essential. Practically all the marsh lands with possible exception of those in Polk county are sour or in an acid condition. They also require both phosphoric acid and potash fertilizer. Wood ashes where these can be obtained in unleached condition, are a cheap and excellent fertilizer to supply the potash. They may be applied at rate of one ton per acre and should be harrowed in thoroughly. When wood ashes are not available the imported potash fertilizer should be used.

To supply the phosphorus* needed the ground rock phosphate is preferable, although ground bonemeal also gives good satisfaction where tried. The ground rock phosphate may be added in the fall of the year at the rate of one-half ton per acre for the first application, and smaller amounts later. If the bonemeal is used, 300 pounds per acre are sufficient. Application of phosphate need not be repeated for three or four years.

The additional supply of nitrogen fertilizers has shown no marked improvement in crop yield. The peat marshes with their large supply of organic matter usually afford more than enough nitrogen in a form available to plants. Wherever barn yard manure is available on the farm it can be added with profit. Where this is done, purchase of commercial fertilizers is unnecessary. As a rule, however, it is best to use the manure on the ordinary soils of the farm where a complete fertilizer is needed, and to apply a special mineral fertilizer of phosphate and potash to the muck soils.

In the Newer Portion.—With cut over land in the northern part of the state selling for about fifteen dollars an acre, the greatest factor in determining the value of cleared land is the cost of removing the stumps, slashings and stones. Assuming

* For a more complete discussion of the management of marshland soils, see Bull. 205, which may be had on application to the College of Agriculture, Madison, Wis.

this to vary from ten to forty dollars an acre, the total cost of cleared upland ready for the plow is from twenty-five to over fifty dollars an acre. Open peat marshes, those containing no wood or brush, can be bought for from three to five dollars an acre. For ten dollars an acre with a combination of deep and shallow ditches they can be drained to a degree that will permit the growth of timothy hay. They can be plowed immediately after drainage at a cost not greater than that of breaking upland. Assuming farther that the fertilizer requirement of the marsh soil can be supplied for a few years at least very cheaply in the form of wood ashes from the saw mills or from the burned brush piles of the upland, the settler in northern Wisconsin can make tame hay land out of peat marshes for less than half the average cost of doing the same with upland. It is probable, however, that for the production of the cereals, it is better for the present to clear upland, than to attempt the more complete drainage of the humus marshes that would be necessary for this purpose.

CHAPTER IV.

AGRICULTURE.

HISTORICAL.

This area like other portions of central and northern Wisconsin, was originally covered with much hardwood and pine, the latter being especially abundant on the sandy lands along the rivers. Only in the western part of the area, mainly in St. Croix county, thinly wooded and prairie lands occur. It was the pine lumber industry that first attracted the permanent settlers to the area. The location of saw mills around which villages and cities were built were the centers from which the agricultural development later proceeded.

The pioneer lumbermen came in from the south, up the Mississippi river and its main tributaries, the Chippewa and the St. Croix. Before the railroads penetrated the area the logs and sawed lumber were floated or towed down the river in rafts. To a certain extent this mode of transportation is still used, though the more rapid shipment by rail is now the usual method.

For a number of years lumbering was the leading industry of the area. For the last 15 or 20 years, however, agriculture has been in the lead and is steadily growing in importance.

First Settlements.—Long before the first permanent settlements were made in this area the region had been visited by explorers and fur traders. Father Hennepin visited the Sioux Indians at St. Croix Falls as early as 1681. "Fort Beau Harnais" trading post was built on Lake Pepin in 1793. Jonathan Carver went up the Chippewa river as far as Chippewa Falls in 1767.

The first permanent settlement in the area was made in 1828 when a saw mill was erected at the mouth of Wilson Creek, the present site of Menomonie. As early as 1839 three mills were in operation in the vicinity of Menomonie. St. Croix Falls was first

settled in 1837, and Chippewa Falls in 1839. A saw mill at Eau Galle was built in 1840. A saw mill was built at Osceola in 1842 and a grist mill in 1848. Hudson was first settled in 1840 and the first farm opened there in 1841. Eau Claire was first settled in 1845. Settlers located in the vicinity of Pepin in 1846, at River Falls in 1848, and at Arkansaw in 1852. The first logging in Barron county was carried on in 1848 and the first farm opened in the southern part of the county in 1855.

Early Transportation.—Before the advent of the railroads, steam boats ascended the Chippewa river as far as Eau Claire, and ascended the St. Croix river as far as St. Croix Falls. River traffic on the Chippewa was abandoned soon after the railroads reached Eau Claire, but river traffic is still important between Stillwater and Hudson and various ports on the Mississippi. Occasionally excursion boats go beyond Stillwater to St. Croix Falls.

The first railroad, now the C. St. P. M. & O. R., reached the area in 1870. The present C. St. P. M. & O. R R. railroad connection between Chippewa Falls and Eau Claire was made in 1875, and the Wisconsin Central, now the "Soo" line reached Chippewa Falls from Abbotsford in 1880. The railroad was built from Eau Claire to St. Paul in 1871–2.

Population.—The growth in population in the nine counties of the area since 1860 is shown in the following table:

TABLE XXII.—*Population of the area from 1860 to 1910* (U. S. Census).

County.	1860	1870	1880	1890	1900	1910
Chippewa	1,895	8,311	15,491	25,143	33,037	32,103
Eau Claire	3,162	10,769	19,993	30,673	31,692	32,721
Dunn	2,704	9,488	16,817	22,604	25,043	25,260
Pepin	2,892	4,659	6,226	6,932	7,905	7,577
Pierce	4,672	9,958	17,744	20,385	23,943	22,079
St. Croix	5,392	11,035	18,956	23,139	26,530	25 910
Polk	1,400	3,422	10,018	12,968	17,801	21 307
Barron	13	538	7,024	15,416	23,677	29,114
Rusk*	.....	.....	.....	.....	.....	11,160
	21,630	58,180	112,269	157,320	189,928	207,291

*Rusk county was organized from Chippewa county in 1901.

The table shows an increase of population for the entire area from 21,630 in 1860 to 207,291 in 1910. From 1860 to 1890 the increase in population was due to the development of lumbering as well as agriculture. Since 1890 the increase is largely

due to the steady growth in agricultural population. The rural population of the southern and well settled counties, Eau Claire, Dunn, Pepin, Pierce, and St. Croix has remained about stationary since 1900. The northern unsettled counties, such as northern Chippewa, Rusk, Barron, and Polk show a steady increase.

Nativity of Population.—Most of the population of the several counties is native born. The following table compiled from the state census of 1905 shows the source of the population:

TABLE XXIII.—*Nativity of population, state census, 1905.*

County.	Total population.	Native born.	Germany.	Norway.	Sweden.	Denmark.	Canada.	Ireland.
Barron	28,376	21,225	1,226	2,648	911	205	713	67
Chippewa	32,000	24,862	2,200	1,766	233	122	1,033	251
Dunn	26,074	20,570	1,857	2,509	219	108	306	99
Eau Claire	33,519	25,893	2,609	2,847	280	99	938	253
Pepin	7,569	6,182	249	54	578	.....	121	29
Pierce	23,433	18,851	872	1,384	1,152	224	251	203
Polk	20,885	15,035	547	1,397	2,126	1,141	346	52
St. Croix	28,716	20,640	1,024	2,208	536	347	602	556
Rusk	9,748	7,824	328	343	226	69	484	17

The population is largely native born. The lowest percentage of native born is in Polk county, and the highest percentage is in Rusk, Pepin and Pierce. A large portion of the native born, however, from one-third to two-thirds, is of comparatively recent foreign parentage. The table shows that in all the counties except Chippewa the most important foreign element is Scandinavian. Of the Scandinavian element, the Norwegian predominates except in Polk county where the Swedes are more prominent. In Chippewa county the Germans are the most important foreign element, with Norwegians second, and French Canadians third. The Canadian element, mainly French Canadian is also important in Eau Claire, Barron, St. Croix and Rusk. The Danes are important in Polk, and there are numerous Irish in St. Croix.

General Conditions of Agricultural Development.—Certain parts of the area in Pepin, Pierce, Dunn and Eau Claire counties, are well settled, the earliest farm settlement dating back 50 to 60 years. Other parts, especially in the northern portion in Polk, Barron, Rusk and Chippewa, though having in general equally as good soils, are still covered with large areas of dense hardwood forests. The soil map of the area showing the distri-

bution of wagon roads, expresses fairly well the distribution of the well settled and the very thinly settled parts of the area.

Proportion of Cultivated and Uncultivated Lands.—The following table gives the total land area in each county and also the amount of land under cultivation in 1885, 1895 and 1905. The percentage of total land under cultivation, according to census of 1905 is also given:

TABLE XXIV.—*Cultivated land.*

Counties.	Total land areas in 1000 acres.	Cultivated land in 1885 1000 acres.	Cultivated land in 1895 1000 acres.	Cultivated land in 1905 1000 acres.	Percentage of total land under cultivation 1905.
Barron	581	43	79	136	24.2
Chippewa	654	91	131	169	25.9
Dunn	540	136	175	218	40.4
Eau Claire	398	111	142	166	41.9
Pepin	152	45	54	62	40.9
Pierce	317	135	158	189	51.6
Polk	597	63	83	124	20.8
St. Croix	455	207	228	252	55.5
Rusk*	583	.....	.....	16	2.8

*Rusk, a part of Chippewa county until 1901.

This table shows the steady growth of agriculture in all the counties of the area. The county showing the greatest improvement between 1895 and 1905 is Barron, with Dunn second and Polk third. St. Croix county has the largest percentage of land under cultivation with Pierce second and Eau Claire third. Rusk county, only recently set off from northern Chippewa has only a small percentage of its area under cultivation.

Farm Buildings. Occasionally log houses are built in the newest settlements, but usually the farm homes are the ordinary type of frame structures. In all the better settled areas, new frame houses much more pretentious than those first built, have been constructed. Houses of brick have been built in many localities, but are not abundant. A very large number of the barns are of the stone basement type. Silos are not abundant but are gradually being built as the interest in dairying increases.

Price of Farm Lands. The value of cleared lands varies considerably in the area depending upon character of soil and also the general location. The best class of farm land is generally

held at from 50 to 80 dollars per acre. Some lands, however, are held as high as 100 dollars per acre. Much of the lightest sand land is held at 20 to 40 dollars per acre. Good farm lands without improvements and with little or no merchantable timber, generally vary at present (1910) from 8 to 20 dollars per acre, the price depending upon accessibility by rail and wagon road, as well as upon character of the soil.

Crops. All the important common crops are grown in the areas. The following table shows the production of the important grain crops in 1904 from the latest available statistics.

TABLE XXII.—*Table showing acreage and production of grain in 1904.*

County.	Barley.		Buckwheat.		Corn.		Oats.		Rye.		Wheat.	
	A	B	A	B	A	B	A	B	A	B	A	B
Barron	3,502	91,893	1,114	17,389	3,242	76,959	31,574	1,145,025	1,245	22,706	3,073	51,542
Chippewa	1,952	54,427	959	16,399	10,792	264,732	42,584	1,742,098	1,913	28,114	2,177	33,542
Dunn	4,674	124,218	1,812	26,391	26,203	777,206	57,992	1,953,278	4,805	57,111	3,862	59,636
Eau Claire	4,152	131,063	2,510	34,885	14,854	386,861	47,639	1,688,520	5,427	68,942	4,556	64,106
Pepin	8,924	279,321	258	3,041	9,746	288,204	13,489	499,215	2,198	24,257	1,810	27,627
Pierce	35,023	1,075,798	158	2,270	15,873	497,307	49,138	1,973,673	4,789	85,035	4,847	80,538
Polk	4,024	120,654	201	3,629	6,622	143,338	38,626	1,391,050	1,235	19,787	3,120	58,914
St. Croix	15,753	447,883	662	10,165	14,148	318,781	93,163	3,270,522	5,465	93,356	3,354	51,591
Rusk	151	4,974	115	1,852	273	7,749	1,308	46,573	51	896	73	1,580

The most important grain crop in the area, in acreage and bushels is the oat crop. From one to three million bushels were grown in each of the counties except Pepin and Rusk. St. Croix is one of the leading counties in the state in the production of oats, usually ranking among the first two or three counties. The acreage and production of oats in 1904 was approximately double that of 10 years earlier.

The next crop in importance is corn. Dunn county leads in the production of corn with Pierce second and Eau Claire third. The increase in the production of corn has not been important in the past 10 years.

Barley is next in importance in the area though wheat is more important than barley in many of the counties. Pierce county leads in barley, producing over one million bushels in 1904, almost as much as the entire remainder of the area. Pierce is one of the leading counties of the state in barley. There has been a considerable increase in production of barley

in the past 10 or 11 years. St. Croix is second in barley and Pepin third in the area.

The wheat crop is relatively unimportant in the area at present though from 20 to 40 years ago it was the leading grain. At present Pierce leads in wheat, with Eau Claire second and Dunn third. At an earlier period St. Croix was the leading wheat county and was very important in wheat raising. There has been a steady decline in wheat raising in all the counties of the area since 1885. In 1885 St. Croix raised 1,807,985 bushels of wheat and in 1905 only 51,591.

Rye and buckwheat are relatively unimportant crops. The production of rye like that of barley has greatly increased in the area.

The potato is an important crop in Chippewa, Barron and Dunn counties. In these three counties the production has nearly doubled in the past 10 or 15 years. On the other hand the production in the other counties except in Eau Claire, shows a decrease. The potato is grown mainly on the sandy loam soils of the area.

TABLE XXIII.—*Acreage and production of potatoes 1885-1905.*

County.	1885.		1895.		1905.	
	Acres.	Bushels.	Acres.	Bushels.	Acres.	Bushels.
Barron	760	86,443	3,164	151,002	5,982	614,336
Chippewa	1,298	153,409	3,810	161,782	6,179	779,509
Dunn	1,344	144,373	3,898	159,486	5,474	602,678
Eau Claire	1,108	133,630	2,495	124,040	2,538	367,485
Pepin	440	42,773	592	21,631	351	43,276
Pierce	1,098	137,726	2,266	115,327	1,369	162,154
Polk	875	103,772	3,092	107,818	23,30	192,679
St. Croix	1,581	180,022	3,643	142,303	1,701	164,632
Rusk					501	55,995

Among the special crops, sugar beets, tobacco, pease and corn for canning are grown in various parts of the area. Tobacco is grown on the sandy loam soil in the vicinity of Chippewa Falls and Colfax and in various other localities in Chippewa, Barron and Dunn counties. Sugar beets are grown in Chippewa county, and to some extent in Eau Claire and Barron, the crop being worked up in the large sugar factory at Chippewa Falls. Pea canning factories are located at Chippewa Falls, Barron

and Rice Lake and a considerable acreage in pease for canning has been developed in these localities.

Hay. The hay crop is an important one and has more than doubled in acreage and tons in the last 10 year period. The table shows the statistics for the census years of 1895, 1900 and 1905. St. Croix has the largest acreage in hay with Barron county second and Chippewa third. Barron county, however, raised the largest number of tons.

TABLE XXIV—*Acreage and production of hay.*

County.	1895. Hay.		U. S. Census 1900 (1899). Wild.		Clover.		Other tame grasses.		1905. Hay.	
	Acres.	Tons.	Acres.	Tons.	Acres.	Tons.	Acres.	Tons.	Acres.	Tons
Barron	.....	21,349	2,513	2,781	861	1,175	42,847	51,096	53,808	80,930
Chippewa	.....	28,826	2,798	3,445	3,791	5,149	44,913	52,561	51,391	77,865
Dunn	.....	35,709	3,390	3,802	3,639	5,028	39,570	47,009	49,587	74,045
Eau Claire	.....	30,628	5,752	7,327	4,079	5,927	26,033	31,149	39,178	58,126
Pepin	.....	9,304	740	931	1,656	2,462	7,737	10,218	10,083	16,351
Pierce	.....	32,561	1,293	1,376	3,514	5,811	30,226	42,204	34,763	58,747
Polk	.....	24,104	4,645	5,350	1,074	1,697	32,065	39,438	47,854	69,501
St. Croix	.....	34,182	2,680	3,026	1,960	2,646	53,924	58,538	59,274	77,347
Rusk	.....	.....	.....	.....	.....	.....	.....	.....	7,756	12,447
	.....	216,663	23,811	28,138	20,574	29,995	277,315	332,213	353,694	527,359

The table shows that the production of hay increased nearly 4 times in the past decade in Barron county; nearly three times in Polk and Chippewa, and about two times in the other counties. The increase in the production of hay follow closely the increased development of the dairy industry in the several counties of the area. In the statistics compiled from the U. S. Census of 1900 it is interesting to note the tonnage of wild hay and of clover. Clover is an especially valuable crop grown in rotation with grains, in order to supply nitrogen to the soil. Eau Claire leads in the acreage of clover, with Chippewa second and Dunn third. The grain raising counties, especially St. Croix and Pepin do not make a good showing with regard to clover. In all the counties an increase in the acreage of clover ought to be made.

Dairying. Dairying is an important industry in all the counties of the area. The value of dairy products exceeds that of

total grain in Barron, Rusk and Polk. In Chippewa the total value of grain is slightly greater than that of dairy products, and in the remaining counties grain considerably exceeds the value of dairy products. The value of the oat crop alone greatly exceeds the value of dairy products in St. Croix, and the oat crop or barley crop alone are almost equal to the dairy products in Polk, Pierce and Pepin counties.

In all the counties, however, there has been a great increase in dairying in recent years. The number of milch cows, and also the product and value has more than doubled in the last ten year period. The greatest increase is shown by Barron, with Polk, second, Chippewa third and Dunn fourth, as shown in the accompanying table.

TABLE XXV.—*Table of dairy statistics.*

County.	1895.		1905.	
	Milch cows.	Value of dairy products.	Milch cows.	Value of dairy products.
Barron	5,795	$74,584	17,767	$349,476
Chippewa	7,143	122,858	17,417	552,192
Dunn	9,758	142,600	20,944	624,435
Eau Claire	8,115	139,776	14,270	449,987
Pepin	3,275	44,983	5,371	165,664
Pierce	9,421	177,057	16,383	516,508
Polk	7,988	106,495	19,693	585,252
St. Croix	10,540	138,579	18,977	695,008
Rusk			2,329	143,138

The statistics in regard to amount and value of dairy products for 1895 are sufficiently complete for purposes of comparison with 1905. The increase in dairying, however, is best shown by the increase in number of milch cows between 1895 and 1905 in the various counties. While dairying will steadily increase in importance over the entire area in the future, it is quite likely that the greatest increase will take place in the northern and eastern counties where the soil conditions for grain raising are not so favorable as in the southwestern part of the area. Dairying, however, should be encouraged and developed as rapidly as possible in the southwestern counties as an important means of maintaining the fertility of the soil in connection with the extensive grain raising.

Live Stock. Live Stock such as hogs, cattle and sheep is an important source of farm revenue. The value of live stock sold in 1904 is shown by the following table:

TABLE XXV. —*Value of live stock sold and consumed, and value of wool, in 1904 State Census, 1905.*

Counties.	Cattle and calves.	Hogs.	Sheep.	Wool.
Barron	$149,574	$87,963	$19,700	$13,803
Chippewa	127,633	128 288	8,496	9,937
Dunn	158,599	278,385	20,425	22,272
Eau Claire	84,685	149,622	6,016	5,989
Pepin	37,616	124,299	5,583	7,650
Pierce	211,541	194,837	47,505	49,570
Polk	170,984	104,923	8,993	8,548
St. Croix	213,946	159,301	21,145	21,783
Rusk	22,284	9,980	1,647	1,355
	1,176,822	1,222,538	139,570	140,907

From the table it may be seen that the annual revenue from the sale of hogs only slightly exceeds that of cattle in the area. The most important county for hogs is Dunn, and for cattle is Pierce. Pepin county ranks highest in hogs in proportion to the size of the county. Sheep and wool is not important as compared with other live stock. Pierce is the leading county in sheep, the value of sheep and wool sold in 1904 being $97,075 more than double that of any other county, and amounting to more than one third of the entire area. Pierce also usually ranks among the first two or three counties in the state in sheep and wool.

In addition to the crops already mentioned all kinds of garden truck are grown, and also an abundance of the common small fruits such as the strawberry, raspberry, blackberry, currant and gooseberry. Of the tree fruits the hardy varieties of the apple and the plum are grown successfully.

Transportation and Communication. Each of the counties of the area is well supplied with railroads, and telephone lines, and rural mail routes. In the well settled parts of the area good roads prevail, and in the thinly settled parts graded roads are built to new settlers as needed. In the vicinity of Eau Claire, some of the sandy roads have been greatly improved by the use of shale.

Markets. The leading cities with their population in 1910 are as follows:

TABLE XXVI.—POPULATION OF CITIES OF THE AREA.

Eau Claire	18,310	New Richmond	1,988
Chippewa Falls	8,893	Durand	1,503
Menomonie	5,036	Barron	1,449
Rice Lake	3,968	Cumberland	1,445
Hudson	2,810	Bloomer	1,204
Stanley	2,675	Ellsworth	1,005
Ladysmith	2,352	Spring Valley	972
River Falls	1,991	Prescott	936

Smaller cities and villages are distributed over the entire area and afford ample means for trade.

Forest Conditions.—The valuable standing timber at the present time is in the northern and northeastern part of the area. Most of the pine forest was removed from 20 to 40 years ago, and very little or no pine is now left. Hardwood and hemlock forests of merchantable lumber, however, are abundant in Rusk, northeastern Chippewa and in the northern parts of Barron and Polk. There are some small tracts of good hardwood timber still remaining also in the eastern part of Pierce, southwestern part of Dunn and in the northeastern part of St. Croix. The hardwoods consist mainly of oak, maple, birch, basswood and ash.

APPENDIX.

CORRELATION OF SOILS OF NORTH WESTERN WISCONSIN AND OF NORTH CENTRAL WISCONSIN.

The area of North Central Wisconsin, a preliminary soil survey of which was completed in 1903, lies immediately east of North Western Wisconsin along the eastern boundary of Eau Claire, Chippewa and Rusk counties.

In each of the areas, 14 soil types are distinguished and shown on the maps of the respective areas. While the number of soils mapped in the two areas is the same, the soils in the two areas differ in many respects.

The soils in the two areas are unlike on account of certain differences in the geological formations. The North Central area is very largely a region of granitic rock, with no limestone formations and no loess deposits. The North Western area on the other hand contains considerable areas of limestone and loess and while it also contains some areas of granitic rock. no typical residual soils on granitic rock are developed. Both areas, however, are alike in being covered with glacial drift and alluvial deposits.

Three soil types developed on the glacial drift, the Colby silt loam, the Chelsea loam, and the Kennan silt loam, are common types in both areas. The Marathon loam and the Mosinee gravelly soil, residual soils on the crystalline and granitic rocks, occur only in the North Central area. The Hartland silt loam, loess soil, and the Cushing loam and Baldwin silt loam, developed on limestone or limestone drift, occur only in the North West area.

Three phases of alluvial or bottom land soils are mapped in each area. Of the alluvial soils, the Rice Lake loam corresponds closely to the Antigo loam, the Chetek sandy loam corresponds closely to the Bancroft sandy loam, and the sterling sand cor-

responds closely to the Wisconsin River sand. The Meridean sandy loam, the type on the lowest terrace of the alluvial bottom, is not mapped separately in the North Central area.

The Auburn loam, residual soil developed on the sandstone, is an important soil in the North West area and corresponds only in a general way to the Mentor sand and Cary sandy loam of Clark and Wood counties. The Mentor sand and Cary sandy loam consists of both upland and bottom land soils while the Auburn loam is a type of upland soil, on sandstone and shale associated with loess deposits.

The Milltown silt loam of Polk county has no closely corresponding type in the North Central area. The Thornapple sandy loam in Chippewa County, and the Harrison sandy soil in Lincoln county, and Amherst sandy loam in Portage and Marathon are phases of drift soils.

Three of the soil types on the glacial drift, the Kennan silt loam, the Chelsea loam, and the Colby silt loam extend across, as mapped, from the North Central area into the North Western area. Owing to the fact that eastern Chippewa county is fairly well opened up to farming at present while the western part of Taylor county was wholly unsettled at the time of the survey of the latter, the separation of the Kennan silt loam from the Chelsea loam in eastern Chippewa county has been made with greater detail than it was in Taylor county. The Kennan loam in Taylor county extends farther south, including a considerable larger portion of the region about Gilman than is shown on the soil map of North Central Wisconsin. In the next edition of the soil map it will be possible to make a more detailed survey of the soils in western Taylor county.

Owing to the fact that loess is of general occurrence over the sandstone of Eau Claire county, as well as to the fact that the sandstone itself contains much shale or clay, the soils of Eau Claire county differ considerably from those on the sandstone of western Clark county where these deposits are not developed. Both the sandstone upland soils and the bottom land soils in Eau Claire county as well as other parts of the North Western area are mapped with much greater detail and on a somewhat different basis than the soils of western Clark county. In general the Mentor sand of western Clark county corresponds

closely with the Sterling sand, the former, however, contains sandy uplands as well as sandy bottoms, whereas the latter type includes only the sandy bottom soil. The Carey sandy loam of Clark county corresponds closely to the Auburn loam of Eau Claire in character of soil, though the former includes bottom lands as well as uplands, whereas the Auburn loam includes only the upland soils.

The Auburn loam type associated with occasional deposits of loess soil extends over a small area about Humbird on the western border of Clark county. In the next edition of the soil map of North Central Wisconsin a more detailed classification of the soil in western Clark should be made.

The various names of the soils in both the North Central and the North Western areas are of local derivation and are applied only provisionally with the plan in mind that probably other names will be used for these soils at some future time when a detailed survey of the soils of the entire state is completed. The soil names used in the U. S. Bureau of soils classification in the detailed surveys of the southern counties of the state will probably supercede many of the names used in the reconnoissance surveys of the northern parts of the state.

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RECONNOISSANCE

SOIL SURVEY

OF

MARINETTE COUNTY

BY
SAMUEL WEIDMAN
WISCONSIN GEOLOGICAL AND NATURAL HISTORY SURVEY
AND
PERCY O. WOOD
UNITED STATES DEPARTMENT OF AGRICULTURE

SURVEY CONDUCTED IN COOPERATION WITH THE UNITED STATES DEPARTMENT OF AGRICULTURE, BUREAU OF SOILS, MILTON WHITNEY, CHIEF.

MADISON, WIS.
PUBLISHED BY THE STATE
1911

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FIGURE.

FIG. I.—Sketch map, showing location of the Marinette County area, Wisconsin 2

MAP.

Soil map, Marinette County sheet, Wisconsin.

PREFACE

The Wisconsin Geological and Natural History Survey is carrying on a soil survey of Wisconsin in cooperation with the U. S. Department of Agriculture and the College of Agriculture of the University of Wisconsin. The primary object of this survey is to make an inventory of the soils of the state; to secure knowledge of the kinds of soil, their physical and chemical qualities, and the area and distribution of each kind. In the reports of the soil survey, therefore, the soils are described, classified, and mapped, as is done in the present report of the survey of Marinette County.

In the northern and more sparsely settled portions of the state the survey is of a rapid and general character, and is termed a "reconnoissance survey." In those portions of the state where substantially all of the land is in farms, the survey is carried on with much greater detail.

In the course of the reports on the soils of different areas general statements are made regarding the use and treatment of types of soil. These statements are carefully considered and are correct in the light of present knowledge. But it is plain that they cannot be based on careful study and experiment on the particular soils with which the report deals. Such an investigation must be carried on by the College of Agriculture after the survey has been completed and a general knowledge of the soils has been obtained. It will take much time and many experiments to determine in detail the proper methods of maintaining and increasing the fertility of soils, and the crops to which they are best adapted. Meanwhile, the statements made in the reports give general advice which will be of service to the farmer. It must be remembered, however, that the main purpose of the report is to describe and map the soils of the county, or other area with which the report deals. Those who receive the reports should preserve them; to be used for reference in connection with bulletins which the College of Agriculture may issue later, and which will be specifically directed to the practical use of the soils.

RECONNOISSANCE SOIL SURVEY OF MARINETTE COUNTY, WISCONSIN.

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DESCRIPTION OF THE AREA.

Marinette County is situated in the northeastern part of the State of Wisconsin, lying adjacent to the southern end of the Upper Peninsula of Michigan, and separated from it by the Menominee River. It is bounded on the east and northeast by the Menominee River, on the north by Florence County, on the west by Forest and Oconto Counties, on the south by Oconto County, and on the southeast has about 15 miles of shore line on Green Bay, an arm of Lake Michigan. The county lies approximately between parallels 45° and 45° 45′ north latitude, and meridians 87° 35′ and 88° 25′ west longitude. Its greatest length is 58 miles from north to south and its width varies from 24 to 32 miles. It is the third largest county in the State, containing 1,413 square miles, or 904,320 acres.

The elevation of Marinette County above sea level ranges from 580 feet on the shore of Green Bay to probably over 1,500 or 1,600 feet in the northwestern part of the county. The Menominee River at the head of Big Quinnesec Falls, in the northern part of the county, has an altitude of 1,020 feet and descends to 580 feet at the harbor in Marinette. The Peshtigo River at the head of Taylors Rapids, in the west central part, has an elevation of 1,227 feet, and falls to 580

feet at Peshtigo Harbor. The altitude of the railroad station at Marinette is 600 feet, Peshtigo 602, Coleman 706, Pound 714, Beaver 662, Ellis Junction 675, Wausaukee 736, Amberg 889 and Pembine 968.

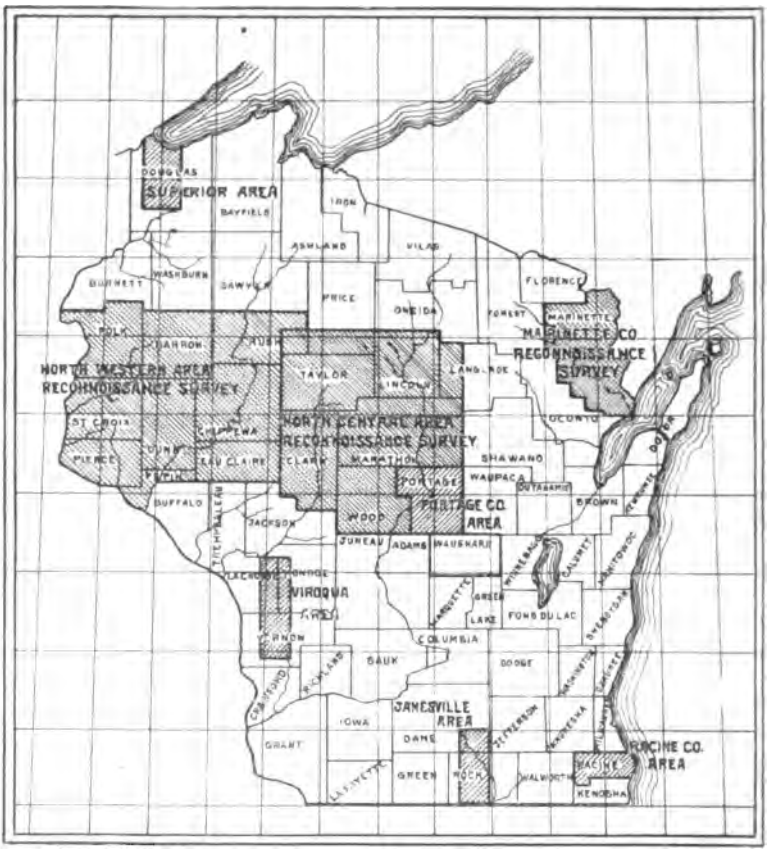

FIG. 1. Sketch map showing location of Marinette County reconnoissance survey, and other soil surveys of Wisconsin.

The topography of the county varies from level plains to gently undulating and rolling areas. The areas of level plains

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The surveys of Marinette Co., of the North Western area, and of the North Central area, including Portage Co., may be obtained on application to the Wisconsin Geol. & Nat. Hist. Survey, Madison, Wis. The surveys of Marinette Co., Portage Co., Racine Co., and the Janesville, Viroqua, and Superior areas may be obtained on application to the U. S. Dept. of Agriculture, Washington, D. C., or from the local Congressman or U. S. Senator.

and rolling lands alternate, their main direction being northeast and southwest. The streams, on the other hand, flow in a southeast direction, at right angles to the trend of the prevailing land features. In conformity with the general trend of the more prominent topographic divisions the small swamps and ridges have their longest direction northeast and southwest.

The most prominent hills in the county are Silver Mountain and Thunder Mountain, both of which reach 400 to 500 feet above the surrounding country. Both these elevations are in the western part of the county, Silver Mountain being in T. 34, R. 17, and Thunder Mountain in T. 32, R. 18.

The drainage of the entire country is toward the southeast. The tributaries of the Menominee River, which forms the northern and eastern boundary of the county, drain about three-fifths of the county, and the Peshtigo River and its tributaries drain about two-fifths. The principal tributaries of the Menominee are the Pike and the Peme Bon Won. The principal tributaries of the Peshtigo are the various streams draining into Lake Noeque Bay and the Little Peshtigo River. There are many small lakes in the county, the most prominent of which are Lake Noeque Bay, having an area of 4 or 5 square miles, and Coleman Lake, with an area of less than 1 square mile.

The stream valleys are relatively broad and shallow; in only a few places are they deep and narrow. Rapids and waterfalls are common. In the western part of the county the Peshtigo River, from Taylor Falls to the Lower Sandstone rapids, falls about 550 feet in about 43 miles. This part of the river is characterized by numerous rapids from 10 to 40 feet in height. Between the rapids the descent is relatively slight. The Menominee and Pike Rivers also contain numerous rapids. These numerous falls and rapids, which are almost entirely found in the area of crystalline rocks, make possible the development of a large amount of electrical power. A $1,000,000 plant has recently been constructed at High Falls on the Peshtigo River for the purpose of supplying power to the city of Green Bay and the intervening country. One of

the largest wood-pulp mills in the country is located at Niagara, in the northern part of the county on the Menominee River, where a fall in the river is utilized for power. The water-power possibilities of northern Wisconsin are becoming more and more important and Marinette County will have no small share in this development.

Marinette County lies in the great timbered area of northern Wisconsin, and agriculture is secondary to lumbering and the manufacturing of timber products. The original growth of white pine has been quite generally removed, as it was long considered the only timber worth cutting. Beginning about 15 years ago, Norway pine, hemlock, and the various kinds of hardwoods, of which there are many in the county, such as basswood, poplar, birch, and jack pine, have been utilized.

There still remain a few tracts of excellent pine owned by lumber companies in the northeast part of the area, and on the Coloma loam there is much fine hardwood, but aside from these areas the valuable timber has very largely been cut. Some poplar and hemlock is used by the paper mills at Marinette, Menominee, and Niagara.

As the process of removing the magnificent forest covering has gone on, few settlers have entered upon agriculture, with the result that the county contains scattered settlements over the large areas of cut-over lands, awaiting the arrival of other settlers to turn the unoccupied areas into prosperous farming sections. In addition to these cut-over areas, which at present are developing a growth of scrubby oak, poplar, and birch, there exist many cedar and tamarack swamps which some day will also be made to contribute to the agricultural resources of the State.

The earliest white settler in the region now comprised in Marinette County was an agent of the American Fur Co., Louis Chappieux, who located on the present site of Marinette in 1796. He retained the monopoly of the fur trade until 1822, on the arrival of William Farnsworth and Charles R. Brush.

Marinette County was organized from the eastern and southeastern portions of Oconto County in March, 1879. The

county when first formed extended up the Menominee River to include township 38, and thus contained what is now the eastern half of Florence County. Florence County was detached from Marinette and Forest Counties in 1884.

The lumber business attracted the first permanent settlers to the county. The first sawmill in Marinette was erected in 1832. The second mill, located at Twin Island, was built in 1841. About 1854 to 1856 several mills were erected in Marinette and Menekaunee, a suburb of Marinette. The original plat of Marinette was laid out and recorded in April, 1858. The first school was organized in 1857 and the first schoolhouse erected in 1858. John G. Kittson, a clerk of the fur company in 1826, was the first man to break ground for a farm in the county. His farm and trading post were located at Wausaukee Bend on the Menominee River.

Agriculture in the county was unimportant until within the eighties. The great tracts of pine land along the Peshtigo and Menominee Rivers, owned by the lumber companies of Marinette, Menominee, and Peshtigo, developed a highly productive business, which gave employment to all the early settlers of the region. The earliest farming in the county was begun about 1870 in the settlements of the Upper, Middle and Lower Sugar Bushes, in the southern part of the county, in what is now the town of Grover.

The Peshtigo fire of October 1, 1871, in which about 1,000 people lost their lives, was a decided blow to the development of the county. The fire followed a long period of especially dry weather and is a memorable day in the history of Marinette County. At that time about 300 families lived in the three Sugar Bush settlements. Only eight houses remained after the fire. The village of Peshtigo was the center of great devastation. The great tracts of thickly forested lands burned over in various parts of the county gave added impetus to clearing the land for farming in the next few years.

In 1860 the population of the towns of Marinette and Peshtigo before the county was set off from Oconto County was 1,044 and in 1875 it was 5,057. Since its organization the county, according to the State census, has reported the follow-

ing population: In 1885, 13,494; in 1895, 19,417; and in 1905, 33,730. The population in 1910, United States census, was 33,812. About one-half the population since 1885 has been in the city of Marinette. Of the entire population since 1885 about two-thirds has been urban and about one-third rural.

Nearly one-half of the early settlers were native-born Americans. The most important foreign-born element was from Canada, of English and French extraction, in about equal proportion. Most of the French Canadians settled in the village of Peshtigo, and on farms about the village of Coleman. The important sources of immigration from Europe before 1885 were Germany, Sweden and Norway, Great Britain, and Ireland. Later the Polish became an important element. Bohemia, Austria, France, and Holland are also represented. In 1905 the number and nationality of the important foreign-born elements were as follows: Canadians, 2,288; Germans, 2,257; Swedes, 1,667; Norwegians, 737; Poles, 757; Danes, 315.

Before the advent of public roads communication in the undeveloped country was very difficult. The Menominee and Peshtigo Rivers were the natural highways for the fur traders and the lumbermen. The supply roads of the lumber companies leading out from Marinette, Peshtigo, and Oconto were an important aid to early communication. For years after the railroads were built into the county the floating of logs down the rivers to Marinette and Peshtigo was the principal method of bringing the timber to the sawmills, and this is still an important means of transportation.

From the time of earliest settlement in the county outside communication has been carried on by vessels on Green Bay and the Great Lakes. The first railroad reached Marinette from Green Bay in 1871. The next year this road, the Chicago & Northwestern Railway, was built from Menominee to Escanaba, Mich. The Peshtigo Lumber Co. at an early date built a railroad from Peshtigo to Peshtigo Harbor, where it connects with a line of barges on the lakes. This railroad later developed into the Wisconsin & Michigan Railway, extending through the northern part of the county. In 1881 the Milwau-

kee Northern Railroad, now the Chicago, Milwaukee & St. Paul, was built through Coleman, Wausaukee, etc., to connect with Ontonagon, Mich. It practically bisects the county in a north and south direction, and has the greatest mileage of any of the roads in the area. In addition to these lines, the Minneapolis, St. Paul & Sault Ste. Marie Railroad traverses the northern part of the county from east to west. The city of Marinette, the county seat of Marinette County, in addition to having three railroads, is so situated as to participate in the Great Lakes traffic, although the principal wharves are in Menominee, Mich., which is about the same size as Marinette, and is situated on the opposite bank of the Menominee River.

Marinette, population 14,610, is the principal town in the area, and is a thriving and prosperous little city, which owes its origin and growth to the lumber industry, still the most important business. Peshtigo, a town of about 2,500, is also a lumber town, and Wausaukee, the next in size, with about 1,200 population, has a large sawmill as its most important feature. Aside from these local markets, together with Menominee, Mich., the iron and copper country of upper Michigan furnishes a most excellent market for all kinds of farm products. Not only can Chicago prices be obtained in the copper country markets, but freight charges are paid in addition, so that the various vegetables and small fruits, grown at present on a very limited scale, as well as potatoes, hay, field peas, and the like, are readily disposed of.

A county agricultural school, established in 1905, is located at Marinette. The school is maintained jointly by the State and county and is doing excellent work in agricultural education. The general science of agriculture is taught and practical demonstrations in farm work in its various phases are given.

A substation of the State experiment station was established in 1909 at Crivitz (Ellis Junction railroad station). The station is devoted to experimental work on crops best adapted to the sand soils and the general management of sandy soils. The results of the investigations will be announced as soon as completed.

CLIMATE.

Northern Wisconsin is famous for its ideal autumn weather. The summers, while warm during the day, almost uniformly have cool nights. The winters are long and usually dry and cold, snow often being on the ground from December to April. The following tables, compiled from the records of the Weather Bureau Station at Florence, Crandon, and Menominee, show the normal monthly and annual temperature and precipitation. Florence is about 15 miles north of the north central part of Marinette County, and Crandon is 18 miles west of the northwestern part of Marinette County. The observations for Menominee, Mich., are taken only a half mile from the city of Marinette, and are thus applicable to southeastern Marinette County.

The climate of Marinette County, like that of most of Wisconsin, is characterized by considerable range in temperature. The ameliorating influence of Green Bay and Lake Michigan on the southeast border of the county is important only from 5 to 10 miles from the shore line. Sometimes a temperature as low as—35° F. is reached in winter, while the mercury sometimes passes the 100° F. mark in summer, giving a range of 135°. The coldest weather usually occurs during the latter part of January and the first of February, and the warmest weather in July and August.

The normal temperature for the winter months ranges from 14.5° F., at Florence and Crandon to 18.6° F., at Menominee. The normal for the spring is approximately the same for the three stations, ranging from 38° to 40.7° F. The normal temperature for the summer ranges from 63.6 F. at Florence to 64.9° F. at Crandon and 65.3° F. at Menominee. The normal for the fall is 43.5° at Florence and 43.3° at Crandon, while at Menominee it is much higher, being 48.3°.

Normal and mean maximum and minimum temperature at Florence, Crandon, and Menominee.

	Florence.			Crandon.	Menominee.		
	Mean temperature, 1893–1907.	Mean of maxima, 1893–1907.	Mean of minima, 1893–1907.	Mean temperature 8 years, including 1907.	Mean temperature, 9 years.	Mean of maxima, 3 years, 1906–1908.	Mean of minima, 3 years, 1906–1908.
December	18.3	25	10	16.7	23.2	31.8	16.6
January	13.3	23	5	11.1	18.1	28.8	13.2
February	11.9	23	3	15.7	14.6	28.6	10.5
Winter	14.5			14.5	18.6		
March	24.0	35	14	26.3	28.2	36.9	19.0
April	39.0	53	29	43.1	39.7	48.9	30.1
May	51.1	66	40	52.7	50.4	57.9	39.6
Spring	38.0			40.7	39.4		
June	61.8	75	48	64.7	61.7	73.0	52.5
July	65.6	80	53	66.8	68.0	77.7	58.3
August	63.3	76	51	63.1	66.8	76.6	56.7
Summer	63.6			64.9	65.3		
September	56.5	67	44	56.8	59.6	71.8	53.2
October	44.3	55	35	45.3	49.5	57.1	39.1
November	29.6	37	21	27.8	35.8	42.9	28.4
Autumn	43.5			43.3	48.3		
Annual	39.9			40.9	43.0		

Normal precipitation and prevailing direction of winds at Florence, Crandon and Menominee.

	Normal precipitation.			Direction of prevailing wind. 1908		
	Florence.	Crandon.	Menominee.	Florence.	Crandon.	Menominee.
December	1.54	1.12	0.52	W.	SW.	SW.
January	1.16	1.46	.76	NW.	N.	SW.
February	1.10	1.08	1.05	NW.	N.	NW.
Winter	3.80	3.66	2.33			
March	2.00	1.48	1.84	NW.	W.	SW.
April	2.44	1.48	1.73	NW.		N.
May	3.89	2.38	3.39	NW.	N.	NE.
Spring	8.33	5.34	6.96			
June	4.15	2.62	3.63	SW.	S.	SW.
July	3.86	3.15	4.36	NW.	W.	SW.
August	3.35	2.70	2.68	NW.	W.	NW.
Summer	11.36	8.47	10.67			
September	3.61	3.76	3.27	NW.	S.	NW.
October	2.86	2.65	1.63	NW.	S.	SW.
November	2.05	2.26	1.18	NW.	W.	
Fall	8.52	8.67	6.08			
Annual	32.80	26.14	26.04			

In summer the temperature of Marinette County is practically the same as at Crandon, which is warmer than Florence, while in winter the temperature of Marinette County is the same as that of Florence, which is warmer than Crandon. The north half of Marinette County is 1 degree warmer for the year than either Crandon or Florence, and the southern half of Marinette County is 1 degree warmer for the year than the northern half of the county. In other words, Marinette County has a more equable temperature than either Florence County to the north or Forest County to the west, due to the ameliorating influence of Green Bay and Lake Michigan.

The annual rainfall of Marinette County averages from 26 to 33 inches for the major part of the area. The amount of precipitation is fairly constant for the winter, and a portion of the fall and spring months, but varies considerably in the summer months. Exceptionally dry periods occur once in 50 years, dry periods once in 25 years, and moderately dry periods once in

10 years. The last exceptionally dry period occurred in the years 1894 and 1896.

The greatest rainfall occurs during the growing season, the table showing 19.06 inches for the period from April to September, inclusive, at the Menominee station, against 6.98 inches for the period from October to March, inclusive. At Florence there are 21.3 inches rainfall in the spring and summer months, and 11.5 inches during the fall and winter.

The data of last and first killing frosts, in the accompanying table indicate the period in which immunity from killing frost can be expected to range from 105 days in the northern part of the county to 140 days in the southern part near Green Bay. As shown by the table, frosts are likely to be late in the spring but are not generally earlier in the autumn than for the southern part of the State. From the table it may be seen that one can not reasonably expect immunity from frost, for most parts of the county, before about the first part of June or after the middle of September.

Dates of killing frosts at Florence, Crandon, and Menominee.

Year.	Florence.		Crandon.		Menominee.	
	Last in spring.	First in fall.	Last in spring.	First in fall.	Last in spring.	First in fall.
1895	May 27	Sept. 27	May 26	Sept. 30	.....	.....
1896	May 26	Aug. 19	Apr. 10	Sept. 2	.....	.....
1897	June 8	Sept. 17	June 8	.....	.....	.....
1898	May 16	Sept. 10	.....	.....	.....	.....
1899	May 25	Sept. 13	.....	.....	.....	.....
1900	June 9	Sept. 8	.....	.....	.....	.....
1901	June 9	Oct. 4	.....	.....	May 12	Oct. 1
1902	June 5	Sept. 12	.....	.....	May 21	Oct. 14
1903	June 12	Sept. 6	.....	.....	May 3	Sept. 24
1904	May 30	Aug. 21	.....	.....	May 16	Sept. 20
1905	May 26	Sept. 13	.....	.....	May 9	Oct. 12
1906	June 13	Sept. 29	.....	.....	May 9	Oct. 9
1907	May 28	Sept. 22	May 28	Sept. 22	May 27	Sept. 30
1908	June 15	Sept. 28	June 15	Sept. 29	May 13	Sept. 29
1909	June 18	Sept. 7	May 18	Sept. 7	May 10	Sept. 27
Average	June 3	Sept. 14	June 1	Sept. 13	May 14	Oct. 2

The following table shows the comparative temperatures and rainfalls of Marinette County, southern Wisconsin, northern Illinois, Iowa, and the Lower Peninsula of Michigan:

Mean, seasonal and annual temperature and precipitation.

	Winter.		Spring.		Summer.		Fall.		Annual.	
	Precipitation.	Temperature.	Precipitation.	Temperature.	Precipitation.	Temperature.	Precipitation.	Temperature.	Precipitation.	Temperature.
	Inches	° *F.*	*Inches*	° *F.*	*Inches*	° *F.*	*Inches*	° *F.*	*Inches*	° F.
Marinette County....	3.26	15.7	6.84	39.5	10.16	64.6	7.75	45.1	28.01	41.2
Southern Wisconsin..	4.66	19.8	9.18	45.3	11.17	67.6	8.56	47.0	33.57	44.9
Northern Illinois.....	5.74	25.0	9.89	48.0	11.07	71.8	7.64	51.4	34.34	49.0
Iowa	3.33	21.5	9.50	47.0	12.46	71.5	6.88	50.6	32.17	47.8
Michigan, Lower Peninsula.....	6.29	21.6	7.65	42.7	8.49	67.3	7.54	48.5	30.31	.....

AGRICULTURE.

The principal industry of Marinette County, as already stated, is lumbering and related manufacturing enterprises, with agriculture second in importance. About two-thirds of the population is in the cities and villages and one-third on the farms. This condition is not unusual, but is characteristic of most of the counties in the northern half of Wisconsin, as well as of many counties of the southern half.

The proportion of farm population to village and city population has remained approximately constant since 1875, the total population showing the rapid increase from 5,057 in 1875 to 33,812 in 1910 already cited. The state census of 1905, however, shows a slightly greater increase in the rural population as compared with that of the city, and this trend will very probably continue in the future, as the lumber industry has already passed its greatest development, while agriculture is still in its formative stage.

The total area of the county is 904,320 acres, of which only about 6.7 per cent in 1905 was under cultivation. The acreage of improved land in the county has about doubled for each ten

year period from 1885 to 1905, the cash value of farm lands also doubling for each similar period. A fair estimate of the percentage of land in the county that will finally be improved is probably 70 to 80 per cent of the total area, and hence it is evident that there is ample room for the future development of agriculture in the county. The statistics for 1910 are also included in the table.

Improved and unimproved acres in farms and cash value of farm land, including buildings.

Year.	Improved.	Unimproved.	Value including buildings.
	Acres.	*Acres.*	*Dollars.*
1885	16,989	34,050	908,335
1895	29,302	123,982	2,177,875
1905	60,257	104,141	4,040,736
1910 U. S. Census	79,474	140,089	6,899,590

In describing the agriculture of the county, therefore, we are concerned with possibilities of future development as well as with the status the industry has already attained. At present the agriculture of the county is practically confined to the south central and southeastern parts of the county, on the Coloma fine sandy loam, Miami fine sandy loam, and Dunkirk fine sand. While there are farms scattered over the other types, there are few localities which are at all thickly settled or which present the appearance of an agricultural community.

The present valuation and selling price of the farm lands in Marinette County is determined largely by the character of the soil. In the older counties of the State, where the agricultural lands are almost all occupied, this factor wholly determines the valuation and selling price, but in the new counties other elements, such as location and density of settlement, may enter into the generally accepted basis of valuations.

The range in prices of farms per acre varies widely, as is usually the case in other northern counties. Farms on the lighter sandy soils in the thinly settled central and northern parts of the county will average between $5 to $15 an acre for

uncleared land and $20 to $45 for cleared lands, including buildings. The prevailing prices of farms on the loam soils in the southeastern half of the county and also on the fine sandy soil between Peshtigo and Marinette generally range between $15 and $25 an acre for unimproved land and from $50 to $90 an acre for improved land. The average prices, though stated between wide ranges, are subject to a gradual change tending toward higher prices for each year, as is usually the case where unimproved lands are opening up to agricultural settlement.

In the southeastern part of the county about Coleman, Peshtigo, and Marinette, where settlements were first made, from 1870 to 1880 the staple crops were wheat, oats, corn, and potatoes. Wheat was the principal money crop. Live stock was raised mainly for home consumption. Many of the earliest settlers depended upon game, mainly deer, for meat. An important market of the early settlers was the lumber camps.

The acreage in wheat was very probably larger in 1875 than that of any other crop. In 1885 (see table) the acreage of wheat was second to that of oats. Since 1885, despite the much larger acreage of improved land, the acreage of wheat remains about stationary. On the other hand, the acreage of oats from 1885 to 1905 has increased about five times, of corn ten times, of barley four times, of rye ten times, of potatoes three times, and of hay five times. The apple crop is increasing in importance, the yield in 1885 being 1,630 bushels, while in 1905 14,563 bushels were reported.

The crop statistics, compiled by the U. S. Census of 1910, are also included and shows a notable increase in all crops excepting that of wheat.

Acreage and yield of more important crops.

Crop.	1885.		1895.		1905.		1910.[2] U. S. census.	
	Acres.	Bush.	Acres.	Bush.	Acres.	Bush.	Acres.	Bush.
Wheat	1,490	27,790	706	12,701	1,556	21,164	885	14,927
Barley	114	2,088	108	2,495	415	9,210	1,409	32,019
Oats	2,070	66,647	5,072	135,256	11,407	299,100	13,029	405,503
Rye	161	2,549	423	7,158	1,200	17,574	2,478	43,989
Corn	112	6,552	818	29,132	1,171	34,101	3,597	94,913
Buckwheat	12	324	79	1,013	363	5,779	430	5,672
Potatoes	754	75,012	1,499	127,611	2,153	253,484	3,689	439,958
Beans and peas.	369	6,674	657	8,951	1,873	34,505	.....	.....
Root crops	246	39,284	59	11,483	238	21,245	.....	.....
Apples	.....	1,630	.....	653	.....	14,563	.....	.....
Sugar beets	.....	.....	.....	.....	.....	[1]4,354	.....	.....
Hay	.....	[1]5,115	.....	[1]10,586	17,914	[1]25,031	23,690	31,988

[1]Tons.

[2] Complete statistics of U. S. Census, 1910, for this and other tables not available.

The Miami fine sandy loam of the southeastern half of the county is especially favorable to apple culture. Such varieties as the Duchess, Hibernal, Patten Greening, Charlamoff, Longfield, and Wealthy are well adapted to the local soil and climatic conditions.

The data relating to acreage and production of beans and peas mainly or entirely relate to field peas. Peas do exceptionally well on the new sandy loams and loam soils, the average yield in 1905 being over 18 bushels per acre. The bean is grown very little in Marinette County. It should be grown more extensively on the sanly soils as an important export crop.

Sugar beets are sold to the sugar factory at Menominee, Mich. While the usual yield per acre is not large, the sugar content of the beets is relatively high.

The development of the live-stock and dairy industry has been as rapid as the development of this industry in other northern Wisconsin counties. The value of cattle and calves sold from 1885 to 1905 increased about six times, of hogs about three times. The number of sheep sold has increased considerably during the past few years.

Number and value of live stock on hand and sold or consumed in Marinette County.

Year.	Horses and mules.		Cattle and calves.			
			On hand.		Sold or consumed.	
	Number.	Value.	Number.	Value.	Number.	Value.
		Dollars.		*Dollars.*		*Dollars.*
1885	1,011	100,655	3,032	69,301	346	8,822
1895	2,104	89,378	5,019	56,064	803	8,969
1905	5,168	391,612	13,316	208,335	3,109	49,850
1910	4,430	462,437	15,678	309,918	.....	.....

Year.	Sheep.				Hogs.			
	On hand.		Sold or consumed.		On hand.		Sold or consumed.	
	Number.	Value.	Number.	Value.	Number.	Value.	Number.	Value.
		Dollars.		*Dollars.*		*Dollars.*		*Dollars.*
1885	956	2,557	379	1,169	1,458	8,714	829	13,276
1895	1,019	1,671	257	532	1,890	9,090	1,749	17,281
1905	1,461	4,287	570	1,674	4,806	23,290	4,202	37,540
1910	3,569	12,152	.....	.....	7,917	50,894	.....	.....

Dairying has increased in importance with other phases of agriculture. Complete statistics are not available for 1885, but in the decade between 1895 and 1905 the number of milch cows more than doubled, the output of butter from the farms increased about three times, and the production of cheese from the factories increased about four times. In 1895 there was one creamery and two cheese factories in the county. In 1905 no creameries were reported, but seven cheese factories were in operation.

TYPICAL DAIRY FARM ON MIAMI SANDY LOAM. SEC. 10, T. 31, R. 22 E.

A CHARACTERISTIC HOME OF A NEW SETTLER ON THE COLOMA FINE SANDY LOAM, T. 31, R 20 E. A SMALL ORCHARD AND CLOVER FIELD IN THE FOREGROUND.

Dairy products of Marinette County.

Year.	Milch cows.		Milk.		Butter.	
	Number.	Value.	Pounds.	Value.	Pounds.	Value.
		Dollars.		*Dollars.*		*Dollars.*
1895	.....	.....	.....	.....	97,383	22,981
1895	2,977	53,744	.....	.....	179,170	32,325
1905	7,176	178,663	296,205	43,897	454,992	91,020
1910	8,335	.....	.....	.....	.....	.....

While the dairying industry has more than doubled during the last decade, its development has not been quite as rapid as that of grain and potato growing. One of the principal reasons for the relatively slow development of dairying is probably due to the low grade of the dairy stock. So far as known, there are no herds of pure-blooded stock of the generally recognized dairy or general utility breeds in the county. There are, however, a few bulls of pure blood, mainly of the Guernsey breed, in the southern part of the county. While many farmers keep a good number of cows, the yield of milk per cow is not large nor especially rich; hence the best results from dairying are not obtainable. It is a well-known fact that it requires as much feed to keep a low-grade cow as it does to keep one of high grade. The yield of milk per cow ought to be increased at least twofold over the present yield to obtain the best results developed in other dairy sections of the State. And to obtain this result, better dairy stock should be developed as rapidly as possible.

A system of farming, with dairying as a principal industry, will not only be profitable, but will develop conditions favorable to the maintenance of the fertility of the soil. The general use of manure and fertilizers should be practiced in any scheme of permanent agriculture. Where the forage crop is not fed on the farm and the manure returned to the soil, the continuous production of grain and hay crops brings about conditions in the soil that result in diminished yields. The selling of hay or other forage crops should not be practiced, unless pur-

chases are made from such sales of concentrated feeds with which to balance the feeding ration. The growing of alfalfa on all soils on which it will succeed should be extended, and also the growing of more clover and other legumes, in order to increase the supply of organic matter in the soils and to add the nitrogen which such plants gather from the air.

A chemical examination of much of the surface soil (0 to 8 inches) of the important types has been made, showing, as usual, a high content of potassium and a variable and, in some cases, quite a low content of phosphorus and nitrogen. Only a general statement in regard to the chemical composition and its relation to the fertility of the soil and the application of particular fertilizers can be submitted at this time.

Chemical analyses of samples representative of the soils of the area have been made by Prof. A. R. Whitson, of the College of Agriculture, at Madison, Wis., the results of which are given in the following table:

Chemical Analyses of soils of Marinette County.

Soil type.	No.	Total P_2O_5.	Total K_2O.	Total N.	CO_2	Organic matter.	Lime requirement per acre.	Litmus test.
Coloma loam	92A	0.15	2.52	0.131	0.073	2.83	5,000	Very acid.
Do	102A	.06	2.22	.130	.136	3.82	5,000	Do.
Superior fine sandy loam	93A	.05	2.41	.062	.017	1.17	2,000	Slightly acid.
Coloma fine sandy loam	94A	.15	2.60	.089	.089	1.45	2,000	Acid.
Plainfield sand	199A	.07	1.92	.067	.034	1.08	5,000	Do.
Coloma fine sand	200A	.09	2.27	.077	.042	1.66	5,000	Do.
Miami fine sandy loam, light phase	201A	.08	2.66	.107	.046	1.98	2,000	Very acid.
Miami fine sandy loam	202A	.12	2.59	.182	.082	3.42	500	Not acid.
Dunkirk fine sand	203A	.05	2.12	.130	.049	3.06	5,000	Slightly acid.

These analyses show a fairly high content of potassium in all the soils.

The chemical analyses of these soils is essentially like that of other soils of Wisconsin or the Northwest.

The supply of nitrogen is fairly good for the heavier loam soils, but quite low in the lighter sandy soils. The supply of nitrogen can be maintained and increased by growing clover, alfalfa and other legume crops. An especially good crop for nitrogen on the light sandy soils, which are very low in both nitrogen and organic material, is mammoth clover.

The supply of phosphorus is fairly good in the heavier loams, but quite low in the sandy soils. The analyses show that the phosphorus in the sandy soils is low, and phosphatic fertilizers on these soils are desirable, especially for crops other than the small grains. Application of barnyard manure, where available, would help these soils, but it will probably be found desirable to apply ground rock phosphate, at the rate of about 1,000 pounds per acre to begin with, and lighter applications of 250 pounds per acre thereafter.

Nearly all the soils, of the area would be benefited by lime. The first requisite is to make applications of ground limestone at the rate of 1 to 2 tons per acre. The cost of this would be about $3 per ton, depending on freightage, and the application of these amounts will last for some time, four or five years at least. Where ground limestone is not available, slaked lime can be used, but in smaller quantity. Clover often fails to get a start on light sandy soil. It is usually advisable therefore to add ground limestone when the field is ready for planting to oats or rye with the clover.

Before going to the expense of applying lime to correct acidity of the soils, or phosphate as fertilizer, it is suggested that the local agricultural school at Marinette or the State experiment station at Madison be consulted.

That system of agriculture is best which allows a rational and comprehensive adaptation of soils to crops under the climatic conditions of the area. While it is not intended to outline such a comprehensive system under the present undeveloped conditions of agriculture, certain suggestions are offered which may be of value to prospective settlers, as well as to those already located on the farms.

The loam soil provisionally named the Miami fine sandy loam and Coloma loam, and locally referred to as "clay" soil, are adapted to all those crops usually grown in the northern States

under a system of general farming. Proper varieties of corn should be selected which will ripen within the average period of immunity from frost. The Early Yellow Dent (Wisconsin No. 8), and Golden Glow (Wisconsin No. 12) should be selected. Common flint is probably best for the wet lands on account of maturing earlier. While wheat can be grown and fair yields produced, the crop tends to decline rapidly in yield, and hence it is not grown extensively. Buckwheat should be sown not later than June. The apple, when established varieties are selected and properly cared for, can be grown successfully for home consumption.

The lighter loam soils, the Coloma loam and the small areas of Superior fine sandy loam, are probably not well adapted to wheat and barley, but to most other grains and root crops suitable to the climate. Peas, with yields of 18 bushels per acre, are grown on the Coloma fine sandy loam. On these types from 100 to 150 bushels of potatoes per acre are commonly secured, and oats, rye, and corn give good average yields. The addition of lime to correct acidity of the soil, and also phosphorous as a fertilizer in some cases would be beneficial.

The sandy soils, the Plainfield sand (the jack pine plain type), the Coloma fine sand (the hilly pine-land type), and the Dunkirk fine sand (the low sand-plain type), are adapted to more specialized crops. Barley and wheat should ordinarily not be attempted. These light sandy soils should be worked with special care in order to maintain and increase their fertility. An ideal rotation[1] of crops for the sandy soil is first year oats or rye, seeding with cdover; clover two years; then a cultivated crop of potatoes, corn, or soy beans. Sufficient dairy and other stock should be raised to maintain the upkeep of the farms.

The light sandy soils are typical truck soils, but under the present conditions of development of the region, general farming with selected grains and root crops and the development of the dairying industry is probably the best sysfem to adopt. Dairying, in fact, should be developed on all the soil, not only for the money profit to be derived but also as an important means in

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1 For management of "Sand soils," see Bulletin 204, Wis. Exp. Sta., Madison, Wis.

conjunction with proper crop rotation and use of commercial fertilizers in developing a system of permanent agriculture.

SOILS.

The soils of Marinette County are predominantly sandy, ranging from light sand to a moderately heavy loam. The upland soils are very commonly grayish or brownish at the surface, and are generally well drained throughout.

The soils of the county are formed mainly from glacial and alluvial deposits overlying granite, sandstone, and limestone. The glacial deposits are very largely composed of the ground-up material of the underlying bed rock, and hence these soils in the area of the limestone are very largely of limestone debris, and in the areas of sandstone and granite are largely of sandstone and granitic material, respectively. On the other hand, the soils of the alluvial deposits consist largely of sand and gravel without regard to the underlying rock, and are of very similar composition over the entire area.

The granite and other crystalline rock of the northwestern part of the county are the oldest formations and are of pre-Cambrian age. The first formation next overlying the crystalline rock is the Potsdam sandstone, of Middle Cambrian age, whose area of outcrop lies in a belt or zone from 6 to 10 miles wide extending northeast and southwest and reaching in a general way from the vicinity of Wausaukee to Lake Nocque Bay. The next formation above the Potsdam sandstone is the Lower Magnesian limestone, forming a zone 5 to 6 miles wide, lying southeast of the vicinity of Beaver and Left Foot Lake. The next overlying formation is the St. Peter sandstone, extending in a narrow belt about one-fourth to 1 mile wide along the east margin of the Lower Magnesian. The next formation, the upper most in the county, is the Trenton limestone, forming a zone from 10 to 15 miles wide in the southeast part of the county, extending from the vicinity west of Porterfield to Marinette and the Green Bay shore. Overlying the bed-rock formation are the surface deposits of glacial drift and the alluvial sands and gravel.

In the northern and northwestern part of the county are belts of terminal moraine, characterized by billowy drift hills and

swamps. These belts were formed at the margin of the ice sheets in their retreat across the county, and trend in a northeast-southwest direction. The soils of the terminal moraines generally contain numerous bowlders, these being commonly granite.

A common feature of the southeastern one-third of the county are hogback ridges of gravel or sand "eskers," which were formed by streams flowing in ice tunnels beneath the glaciers. Most of these eskers run in a northeast-southwest direction and usually extend along or through swamps.

The level plains of sandy soil, generally containing more or less gravel in the subsoil, are stratified deposits and were formed in water, which may or may not have been connected with the ice sheets. The sand plains are quite variable in area and have their greatest length in a northeast-southwest direction.

In the northwestern part of the county in the vicinity north and south of Dunbar are small patches of red calcareous clay evidently old lacustrine deposits like those occurring along the shores of Lake Superior and Lake Michigan and in the Fox River Valley.

In this connection may be mentioned the old shore line of Green Bay which extends across the southeastern part of the county and forms the approximate border of the level tract of sand and peat soil lying between Peshtigo and Marinette. This abandoned shore line, 40 feet above the present level of Green Bay and Lake Michigan, was the border of the lake at the Algonquin stage of the Great Lakes. This shore line may be seen near Wilcox Station, also about 2 miles west of Peshtigo, and about 2 miles south of Bagley Junction, whence it turns to the northeast passing through the county 3 or 4 miles north of Marinette and Menominee. It marks a much later stage in the history of the Great Lakes than the one during which the red calcareous clays about Dunbar were deposited.

Considering the geological derivation and process of formation of the various soils, all the principal soils are formed either by weathering of glacial till overlying the bed-rock formation, or by weathering of water-deposited sands in old stream or old lake bottoms. The Miami fine sandy loam is derived from glacial till over the Trenton limestone and the

subsoil consists almost wholly of limestone dèbris, varying from fine powder to large fragments and bowlders, the bed rock being generally from 5 to 20 feet below the surface.

A light phase of the Miami fine sandy loam is derived from glacial till overlying Lower Magnesian limestone, St. Peter sandstone, and the Potsdam sandstone, the subsoil consisting mainly of limestone dèbris and sand. The Coloma loam is derived from glacial deposits overlying the crystalline formations, and consists wholly of dèbris of granitic rocks. The Coloma fine sandy loam and the Coloma fine sand are derived from glacial material within the general area of the sandstone and granitic formations, and are largely of terminal moraine deposits. The Superior fine sandy loam is derived from alluvial sand associated with and overlying red lacustrine clay.

The Plainfield sand is derived from the weathering of alluvial sand and gravel overlying various rock formations. The Dunkirk fine sand is derived from the weathering of delta or estuarine sands deposited in former Lake Algonquin, whose shore lines are about 40 feet above the present level of Green Bay.

Of the unclassified soils Peat consists of decomposed humus and marsh vegetation; Muck consists of a mixture of humus with sand and clay; and Rock outcrop consists of areas of abundant rock exposures, mainly of granitic character, in the northern parts of the county.

With relation to the native forest growth developed on the various soils, the nature of which was used as a general index of the character of the soil, the Miami fine sandy loam and the Coloma loam are characterized by relatively dense growths of hardwoods and hemlock, with large white pine in local areas. The Coloma fine sandy loam and the Superior fine sandy loam support a mixture of hardwoods and pine, the pine predominating. The Coloma fine sand is characterized by a growth of pine including white, Norway, and some jack pine. The Plainfield sand is characterized typically by a growth of jack pine and some Norway pine. The Dunkirk fine sand, relatively low sandy land, is characterized by a rather dense growth of white and yellow poplar, soft maple, scrub oak,

white birch, jack pine, some Norway pine, and in low wet places mixed tamarack and cedar.

Below is given a table stating the actual and percentage area of the various soils of the county as shown on the accompanying soil map.

Areas of different soils.

Soil.	Acres.	Per cent	Soil.	Acres.	Per cent
Coloma fine sand	199,872	22.1	Coloma loam	58,176	6.4
Coloma fine sandy loam	163,008	18.0	Dunkirk fine sand	29,952	3.3
Miami fine sandy loam.	43,776	17.4	Peat	21,312	2.4
Light phase	114,048		Superior fine sandy loam	1,728	.2
Plainfield sand	151,488	16.8			
Muck	120,960	13.4	Total	904,320	

MIAMI FINE SANDY LOAM.

The Miami fine sandy loam consists of a gray sandy to silty loam containing some small stone to a depth of 8 or 10 inches, underlain with silty loam containing somewhat larger rock fragments and extending to a depth of 24 to 30 inches. Below 24 to 30 inches stones and bowlders are generally abundant. The bed rock of limestone is struck at depths of 3 to 15 feet of the surface over large portions of the area. The loose stone is almost wholly of limestone material from the underlying formation. Stone piles are a characteristic feature over much of the cultivated parts of this type.

The soil type occurs mainly in the town of Grover and in the southern part of Porterfield. It is derived from the weathering of glacial drifts over limestone, and like most soils of glacial origin is somewhat variable in composition from place to place.

The surface varies from gently sloping and undulating to nearly level. The type quite generally occupies upland areas and slopes above the stream beds and swampy tracts. The slopes are so gentle that such objectionable features as rapid soil erosion and gullying are not likely to be developed. They are nowhere too steep for cultivation. Occasionally fields of

this soil type are so level that the use of tile drainage would be beneficial. In general, however, the loose texture of the soil, as well as the undulating surface, gives such good natural drainage that underdrainage is unnecessary. A typical farm on this soil is shown in Plate I.

This soil was originally heavily timbered with hard woods and white pine. The pine has been cut for years, but in many places the hardwoods still remain. The latter consist mainly of sugar maple, birch, and beech, with a variable amount of hemlock, oak, elm, ash, basswood and poplar. Three of the earliest agricultural settlements in the county were established upon this type of soil in the town of Grover. They were locally known as the Lower, Middle, and Upper Sugar Bushes, on account of the abundant growth of sugar maples in the settlements.

The forest growth of white pine and hard woods was not uniformly distributed over this soil. Over considerable areas dense hardwood forests predominated, but in some places, usually in areas of small extent, the white pine grew in great abundance even to the exclusion of the hard woods. Where the pine greatly predominated the surface soil generally contains more sand than elsewhere, but the subsoil conditions are much the same as in areas covered with hard woods.

The groundwater level in this soil is generally from 10 to 30 feet below the surface. Sufficient water for domestic purposes, therefore, can be obtained generally in the drift overlying the limestone or a few feet in the limestone. Occasionally, however, wells are drilled from 50 to 100 feet into the limestone before a sufficient supply can be obtained. Much of the soil is underlain by a clayey subsoil which tends to hold the moisture sufficiently near the surface to be available for the growing of crops.

The Miami fine sandy loam is the most fertile soil in the county, and all the staple farm crops are successfully grown upon it. Oats is the principal grain crop, the acreage greatly exceeding that of all other grains combined. The yield varies from 25 to 40 bushels per acre, the average yield being about 30 bushels. Corn is the next most important crop, the yield per acre being about the same as that of oats. In growing corn on this soil, as well as on other soils in the county, the average length of the period

of immunity from frost should be taken into consideration, and only such varieties selected as will ripen within this period. The Early Yellow Dent (Wis. No. 8) and Golden Glow (Wis. No. 12) as well as flint corn, will ripen within the average period of freedom from frost. Wheat and barley are grown to a slight extent, the usual yield of wheat being 15 bushels and of barley about 20 bushels per acre. Some rye is grown, the average yield being about 16 bushels per acre. The yield of potatoes ranges from 125 to 150 bushels. Pease do exceptionally well, the yield being 15 to 20 bushels per acre. Apples and the various kinds of berries can be readily grown. Sugar beets are successfully grown on many farms.

This loamy soil is especially well adapted to apples. The climatic conditions, due to the moderating influence of Green Bay and Lake Michigan, as well as the character of the soil, with its high content of limestone material, are very favorable to their culture. Most of the apples grown in the county are on this soil type. By properly spraying and otherwise caring for the trees, there are good prospects for the successful raising of such varieties of apples as the Dutchess, Hibernal, Patten Greening, Charlamoff, Longfield, and Wealthy for the home as well as for the market.

Dairying is important on this soil, although only a relatively small number of farmers have silos. The principal feed of cows is mixed hay. Hay is an important crop, averaging about 1 and one half tons per acre. Clover is grown to some extent, but not extensively. Millet and some small grains and corn are occasionally grown for forage. The soil is well adapted to dairying and this industry should be developed. Alfalfa has been successfully grown on this soil, and it should be more widely raised.

Because of its adaptation to all the ordinary crops and because of its location this type constitutes the highest priced land in the county, the prices usually ranging from $50 to $90 an acre.

Light phase.—There is a light phase of the Miami fine sandy loam which is of extensive occurrance. It is found in the southeastern half of the county. The main area lies in a belt trending northeast-southwest through the town of Pound, eastern

Beaver Lake, and northern Porterfield. Isolated areas lie farther west in the western half of Beaver and in Wausaukee. The surface soil consists of a grayish medium to fine sandy loam, with depth of 6 to 10 inches, resting usually on a brownish fine sandy loam, which extends to a depth of 24 to 36 inches. The character of the subsoil is somewhat variable, ranging from fine sandy loam to a sandy clay mixed with some stones. Below 24 to 36 inches there is generally a mixture of sand, gravel, and bowlders. This phase of the Miami fine sandy loam contains more sand and less stone than the other phase of this soil. Usually the more clayey phases of the soil are the most stony.

The surface is usually very gently sloping, though in places it is undulating to hilly. The more undulating areas are in the vicinity south of the village of Wausaukee and in the western part of the town of Beaver. Even in the most uneven areas, however, the slopes are not too steep for cultivation. Over most of the areas in the towns of Pound and eastern Beaver Lake the surface rises gently from 10 to 40 feet above the adjacent low tracts and swampy areas along the stream beds.

The soil has its origin in the weathering of glacial drift over a sandy limestone and sandstone. Being derived from glacial drift, it is somewhat heterogeneous in character and the texture and composition of the subsoil lacks uniformity. The lower Magnesian limestone formation which underlies the main area of this soil contains considerable sand, and the weathering of the glacial dèbris worked up from this formation has resulted in a soil consisting of sand and limestone material varying in fineness from flour and small fragments up to large bowlders of lime rock. Mixed with the local limestone are a few bowlders of crystalline rock derived from more distant sources. Along the streams, especially the larger ones, such as Beaver Creek, Little Peshtigo River, and Peshtigo River, these are sandy tracts due to the action of these streams. In the areas of this soil are some gravel and sand ridges, locally known as "hogbacks," which owe their origin to glacial streams flowing in tunnels beneath the glacial ice sheets. Most of the important sandy tracts along the streams and the sand and gravel ridges of subglacial origin are shown on the soil map.

Probably about one-third of this light phase of the type is

under cultivation. Originally it was covered with dense hardwood and white-pine forests. In some areas the pine greatly predominated, in others the hardwoods. The principal hardwoods are beech, maple, and birch, with a variable amount of hemlock, oak, elm, and basswood.

The level of ground water is quite generally from 10 to 40 feet below the surface. Abundant water for all domestic purposes can usually be obtained from the surface formation overlying the bed rock. In some places the wells penetrate the underlying formation of limestone.

About the same crops are grown on this light phase as on other parts of the Miami fine sandy loam. Oats constitute the principal grain crop with wheat next in importance. Potatoes are also an important crop. The yield of oats per acre varies from 30 to 40 bushels and potatoes from 125 to 195 bushels per acre. Barley is grown to some extent, yielding between 20 and 30 bushels per acre. Peas do exceptionally well, yields of 25 to 35 bushels per acre being often reported. Hay is a good crop, mixed clover and timothy usually yielding 2 to 3 tons per acre.

Dairying and stock raising are not as important as they should be. While there are two or three cheese factories within the area of this soil, the average amount of milk obtained from the cows is small, as compared with average conditions over the State. The breed of milch cows should be improved and more attention paid to care and feed of the herds.

The farm values usually vary between $50 and $85 an acre for improved land and about $15 to $20 for unimproved land.

The following table gives the average results of mechanical analyses of the soil and subsoil of the Miami fine sandy loam:

Mechanical analysis of Miami fine sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
22753, 22755	Soil	0.9	5.9	9.4	24.6	18.5	33.1	7.4
22754, 22756, 22759	Subsoil	1.7	7.0	8.4	24.5	19.5	27.5	11.1
Light phase:								
22745, 22747, 22751	Soil	0.7	6.2	12.5	29.4	14.8	29.9	6.3
22746, 22748, 22752	Subsoil	1.3	7.3	13.3	28.7	16.5	22.7	10.2

COLOMA FINE SAND.

The Coloma fine sand, to a depth of 8 to 12 inches, consists of yellowish-brown fine sand. The subsoil, to 36 inches, is a yellow fine sand, which becomes slightly coarser in the lower depths. In the lower subsoil rock fragments and bowlders are sometimes found, and to some extent these are scattered over the surface. This type owes its origin to the last ice sheet and is largely cleared from terminal moraine. In some places it does not differ materially from the Plainfield sand, except in topography, which in the case of the fine sand is rolling to moderately hilly. Natural drainage is good; in fact there is more likelihood of excessive drainage than of lack of drainage.

The fine sand is preeminently the pine soil of the area, it having been originally covered with a heavy growth of white pine, with some Norway. At present, the timber growth consists largely of scattered white pine, considerable Norway pine, and in some local areas jack pine and small oak. Like the Colmoa fine sandy laam, the fine sand occurs in northeast-southwest belts, with alternating areas of Plainfield sand, the latter mainly representing an older soil covering of the region on which the fine sand was deposited by thelatest ice sheets.

Also like the Plainfield sand and Coloma fine sandy loam, the Coloma fine sand is in a practically undeveloped state. Nearly all these types, together with the Coloma loam, Superior fine sandy loam, Muck, and Peat, are in their virgin state, except that the timber is largely removed. On the surface of much of the upland areas is found a layer from one-half inch to 2 inches in thickness, of dark or black material, representing accumulations of organic material.

The Coloma fine sand, like the Plainfield sand, is probably best adapted to a system of general farming restricted to certain grain crops and to dairying. It is a typical truck soil, but under the present condition of agricultural development and settlement of the region, location of markets, etc., it can not be utilized to advantage for the growing of truck. It is a soil which needs "body" added to it in the shape of manure and green crops plowed under. Early maturing crops, such as green corn, peas for canning, tomatoes, cucumbers, etc.,

should do well on this type. At present it gives moderate yields of excellent potatoes, and fair yields of rye, mixed hay, oats, and corn.

By proper management the farms on this soil can be made to yield good returns, many thrifty farms having already been developed upon it. Legume crops, to add nitrogen to the soil, should be included in the crop rotation. Following clover, good crops of peas and beans can probably be grown.

Average yield on the Coloma fine sand are about as follows: Corn, 20 to 35 bushels; oats, 25 to 35 bushels; peas, 12 to 18 bushels; potatoes, 100 to 150 bushels; and rye, 12 to 18 bushels. Practically no barley or wheat is grown.

Unimproved or wild land is held at about the same price as the Plainfield sand, viz., $5 to $20 an acre. Improved farms are sold at $30 to $50 an acre.

The following table gives the average results of mechanical analyses of the soil and subsoil of this type.

Mechanical analysis of Coloma fine sand.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per ct.	*Per ct.*	*Per cent.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
22,733, 22737.....	Soil.....	0.1	5.5	14.6	35.4	23.4	15.2	5.2
22,734, 22738.....	Subsoil...	1	4.6	13.6	41.9	29.9	7.1	2.4

COLOMA FINE SANDY LOAM.

The Coloma fine sandy loam has a top soil, 10 to 12 inches deep, of yellowish-brown, smooth, mellow, fine, to medium sandy loam. The subsoil to a depth of about 24 inches is a light-colored sandy loam, while from 24 to 36 inches is found a light yellow medium sand. The type is by no means uniform, being of glacial origin, and varies from neary pure sand to a heavy sandy loam. The major portion, however, is as described above.

The Coloma fine sandy loam is a terminal morainic type, and has a rolling to hilly topography. It is naturally well drained, but is rarely too hilly to be easily cultivated. Stones and bowlders are more or less plentiful, but seldom occur in

such quantities as to interfere with cultivation. This soil, like most of the important types in Marinette County, lies in northeasterly-southwesterly belts, that being the general distribution of the formations left by the last sheet of ice.

The timber growth is mixed pine and hardwood, being largely white and Norway pine, white birch and red oak. Hemlock, basswood, maple, and elm do not thrive as they do on the heavier Miami fine sandy loam and the Coloma loam.

Very little of the Coloma fine sandy loam is under cultivation, as is true of all the types in Marinette County, with the exception of the Miami fine sandy loam and the Dunkirk fine sand. The home of a new settler on this type is shown in Plate II. However the few farmers located on the type are well satisfied with it and report fair yields, as follows: Oats,20 to 40 bushels; potatoes, 100 to 200 bushels; pease, 15 to 20 bushels; and hay, 1 ton to 1½ tons. This soil, like practically all the other sandy soils in the county, is low in organic matter, and after the first few years of cultivation should be liberally manured. Potatoes are the crop probably best suited to this type, and rye, buckwheat, and bush fruits should be profitable crops. The incorporation of organic matter should not be neglected, as is so often the case in newly settled districts, because of the scarcity of stock. Crops of rye, vetch, and clover, plowed under, preferably in the fall, would greatly benefit and build up such soils. One or more legumes should be included in the rotation, and all manure carefully saved and used. By judicious management the soil can be made to increase instead of decrease in productiveness and value. At present the Coloma fine sandy loam can be bought for $10 to $20 an acre in an uncleared state. The improved lands sell from $40 to $60 an acre.

The following table gives the average results of mechanical analyses of the soil and subsoil of this type:

Mechanical analyses of Coloma fine sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
22741, 22749.....	Soil.....	0.6	6.5	10.8	20.4	20.6	34.0	6.8
22742, 22750.....	Subsoil.	1.4	7.6	8.8	17.6	24.0	32.9	7.2

PLAINFIELD SAND.

The Plainfield sand to a depth of 6 to 8 inches, consists of yellow medium to coarse sand, sometimes slightly loamy. From 8 to 36 inches the material is a yellow medium to coarse sand, growing lighter in color and coarser in texture with depth. Some pebbles and fine gravel are found in the lower subsoil.

As a whole, the soil is free from stones and bowlders, although outcrops of rock are sometimes found within the general soil area, and also an occasional erratic or glacial bowlder. The material composing this type was deposited by streams, and probably antedates the soils in the area which were formed as a result of the latest glacial action.

The soil is locally known as "sandy land," "jack-pine land," "sand plains," etc. The typical timber growth consists of jack pine and scrub oak, with occasionally some Norway and a very few white pines. The surface of the ground is usually covered with brake, sweet fern, blueberry bushes, and wild oat grass. Jack pine is characteristic of the type. The jack pine occurs sometimes on other soils, but only to a limited extent, the medium to coarse sand being its natural habitat.

The topography is level to gently rolling, being usually nearly level, as its alluvial origin would indicate (Pl. III, fig. 1). In some localities, however, as in the area southeast of High Falls, windformed dunes occur in such numbers as to give the type a rolling surface. These dunes are often of slightly finer texture than the soil of more level areas, consisting of clean, loose sand, and are considered less valuable than the main type. Other and larger sand hills occur less frequently, being eskers, or deposits formed by glacial water under ice.

The Plainfield sand is an extensive type, covering an area of 151,488 acres, or 16.8 per cent of the county. Although the surface is level to undulating, the porous character of the soil and the depth and coarseness of the subsoil give good natural drainage. The level character of the land and the comparative ease of clearing often impress newcomers, especially those from the prairie States, so favorably that they purchase farms on this type in preference to those supporting hardwood, although the prices may be nearly the same. Satisfactory yields

FIG. 1. TYPICAL VIEW OF PLAINFIELD SAND, UNDEVELOPED, JACK PINE PLAINS. SEC. 4, T. 36, R. 20 E.

FIG. 2. VIEW OF FARM DEVELOPED ON THE PLAINFIELD SAND. SEC. 5, T. 34, R. 20 E.

FIG. 1. VIEW OF COLOMA LOAM SHOWING TYPICAL DENSE HARDWOOD FOREST NEAR GOODMAN.

FIG. 2. VIEW OF NEWLY CLEARED FIELD ON COLOMA LOAM AT

can be produced on the Plainfield sand only with heavy applications of manure. Green manures, especially legumes, are highly beneficial and should be more generally used. A common mistake is to grow several crops of oats or other grains upon newly cleared land, thus reducing the productiveness to a low stage before a system of building up the soil by growing clover and other legumes is begun. By proper farm management good stands of clover can be produced. Clover can be followed by a money crop which will do well. The bean crop, though rarely grown on this soil in Marinette County, is well adapted to sandy soils of this character and could be grown with profit.

While a good living can be obtained by farmers on this soil, it should be emphasized that the type is not especially productive and that care should be taken at the outset not only to maintain the original productiveness of the land but to practice some system of farming that will tend to increase this productiveness from year to year. That prosperous farms can be developed on the Plainfield sand, when rightly managed, is shown by the presence of some thrifty farms in a number of places. (Pl III, fig. 2.) At the same time there are some abandoned farms on the type which may be expected with poor management.

The type seems best adapted, when operated along general lines, to potatoes, rye, and clover. Fair crops of potatoes are readily grown, the tubers being of excellent quality. More satisfactory yields of buckwheat and rye are secured under the prevailing farm management than of oats or corn. The type is entirely too light for either wheat or barley or sugar beets, although what few beets are grown on the light soils in the area have the compensating factor of a higher sugar content.

But little corn is grown on this type, and much of the product is used for fodder. Twenty to 30 bushels per acre is a good yield. Other crops yield as follows: Oats 20 to 30 bushels; rye, 10 to 15 bushels; buckwheat, 12 to 15 bushels; peas, 10 to 15 bushels, hay, three-fourths ton to 1¼ tons; and potatoes, 75 to 150 bushels per acre. A rotation quite commonly followed is corn or potatoes, oats, and hay, the mowing lands being left as long as they are considered profitable. Pas- usu-

ally is put on the new fields, followed by corn or potatoes. A rotation better adapted to this type would be potatoes, field peas, and mixed hay, leaving the sod not longer than two or three years. The peas could be sold at a good price, the oats or other concentrates purchased. As more land is broken up and more stock kept, fodder corn could be grown in the same place in the rotation as potatoes. This rotation is only tentative; more satisfactory ones may be suggested by practice. There is no question, however, that better rotations than of corn, oats, and grass, leaving the grass down for a long period, can be worked out and used on this soil.

At present prices for the Plainfield sand range from $5 to $18 an acre for "wild" or unimproved land, depending on the location, and $30 to $50 for cleared land.

The following table gives the average results of mechanical analyses of the soil and subsoil of this type:

Mechanical analyses of Plainfield sand.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
22727, 22729, 22731, 22739.	Soil.....	0.5	17.8	30.9	33.9	5.8	6.5	4.5
22728, 22730, 22732, 22740.	Subsoil.	.5	17.2	31.1	38.8	6.5	2.7	3.0

DUNKIRK FINE SAND.

The soil of the Dunkirk fine sand consists of a gray to dark brownish-gray fine sand to fine sandy loam, with a depth of 8 to 10 inches. From this depth to about 18 inches occurs a pale yellow fine sand and from 18 to 36 inches a brighter yellow, fine sand, sometimes slightly mottled.

The topography is level to gently undulating, although in some local areas sand dunes and eskers are so numerous as to give a hummocky surface. The type seems to be a delta deposited in glacial Lake Michigan or Lake Algonquin by streams from the ice sheet to the north and west. There is only one area of this character in Marinette County. It extends from a few miles north of Marinette south along Green Bay to the county

line and is about 6 miles wide. Beyond the county limits it reaches south along the shore nearly to the city of Oconto, retaining practically the same width as in Marinette County. The western edge of this area is somewhat more loamy than the rest, being influenced by the Miami sandy loam. The old beach line of Lake Algonquin constitutes the boundary and is sharply defined in only a few places, being about 40 feet above the present level of Lake Michigan, while the average elevation of the Dunkirk fine sand is probably about 10 to 20 feet above the lake.

In its primitive state this type was covered with a thick growth of jack pine, red oak, and white birch, white and yellow poplar, and some white and Norway pine, and in the wet places with tamarack and cedar. Many scattered areas of Peat, slightly lower than those of the surrounding soil, occur. These, when cleared, or where not forested, are used for hay, of which from three-fourths ton to 1½ tons per acre of rather coarse quality is secured. Where forested, peat supports tamarack, cedar, alder, and a little elm, birch, and ash. The Dunkirk fine sand, as a whole, has a very flat surface. The water level is only 5 to 10 feet below the surface, and in many minor depressions the soil shows grayish white mottling, due to imperfect drainage. In wet seasons the higher lying fields give much the better results, while in dry seasons the reverse is true.

This soil is a typical truck soil, but it is used at the present time mainly for general farming. Rye, hay, and potatoes are the leading crops; oats and little corn practically complete the list, The average yield of rye is 15 to 18 bushels; of hay 1 to 2 tons, and of potatoes from 100 to 125 bushels per acre. Oats do not yield especially well, ordinarily 20 to 30 bushels per acre. Corn yields from 25 to 40 bushels, depending largely on the season.

Owing to its proximity to the towns of Marinette, Menominee, Mich. and Peshtigo, to its productiveness under judicious management,and ease of cultivation, the Dunkirk fine sand is held at rather high prices—from $50 to $75 an acre. It is a type which responds readily to manure, and this fact, together with its nearness to market, makes the keeping of cattle especially profitable. Dairying, mainly for the production of butter, is prominent on this type. A few are starting in the truck business on a small scale and doubtless in a short time the adapt-

ability of this soil to the trucking industry will be more clearly recognized, and an important business will be developed, with the cities of Marinette and Menominee as the primary markets. Chicago and North Western Railway traverses the type, and this fact, together with direct water transportation to Milwaukee, Chicago, and other large Lake cities, will have an important bearing on the development of the soil in the production of the less perishable kinds of truck crops.

The following table gives the average results of mechanical analyses of the soil and subsoil of this type:

Mechanical analyses of Dunkirk fine sand.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
22717, 22719, 22721.....	Soil.....	0.1	0.6	2.9	59.8	18.5	11.8	6.0
22718, 22720, 22722.....	Subsoil.	.0	.2	5.4	73.6	16.3	2.5	1.8

SUPERIOR FINE SANDY LOAM.

The soil of the Superior fine sandy loam consists of 6 to 8 inches of gray to reddish medium textured sand. Underlying the sand, and rather sharply separated from it, occurs a stiff, tenacious, very impervious red clay, the red color having a peculiar pinkish red or light chocolate tinge. The clay subsoil is lacustrine in origin, having doubtless been laid down at the same time as the Superior clay near Green Bay, Duluth, and Superior. The sandy topsoil is of later glacial origin, having been deposited on the clay by subsequent glacial action. This covering of sand is of varying thickness; in some places the clay subsoil lies practically at the surface, while in others the sand is 2 feet deep.

This type is found only in limited areas in Marinette County. The different isolated patches, north and south of Dunbar, evidently lie in an old drainage basin or depression. In general the topography is level to gently undulating, but the soil is nevertheless fairly well drained, as is indicated by the original timber growth of white pine.

The Superior fine sandy loam is a very good general farming soil. Its areal extent in Marinette County is so limited

as to make it comparatively unimportant, but it is known to be well adapted to clover and timothy for hay and pasture, to potatoes, and root crops. It is especially suited to strawberries and raspberries and other bush fruits. Some such special industry will doubtless be developed on it in time, as the mining country to the north furnishes an excellent market for the fancy as well as the staple farm products.

The following table gives the results of mechanical analyses of the soil and subsoil of this type:

Mechanical analyses of Superior fine sandy loam

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
22757.....	Soil.....	0.3	5.5	14.7	52.3	13.6	11.1	3.2
22758.....	Subsoil.	.0	0.4	1.0	3.3	4.0	53.6	37.7

COLOMA LOAM.

The soil of the Coloma loam is a brownish fine sandy to silty loam, with a depth of 6 to 8 inches. The surface 2 or 3 inches often has a grayish color. From 8 to 18 inches the subsoil consists of brown sandy loam to loam. Below 18 inches there occurs an increase in the content of sand, and the subsoil as a whole is generally lighter and more sandy than the surface soil. Throughout the soil and subsoil are found many stones and bowlders.

This stony loam soil, which is known locally as heavy hardwood land, lies in the northwestern part of the county. It is derived from the weathering of glacial drift overlying granitic rocks of various kinds. The surface is very gently undulating. There is a difference of 10 to 50 feet between the elevation of the lower lands along the streams and the adjacent higher land, but the gentle slope as well as the character of the soil tends to prevent damaging erosin.

This soil covered with dense forests of hardwoods and hemlock (Pl. IV fig. 1), has a wide extent over Forest County and the adjacent region to the west. In Marinette County it is undeveloped agriculturally, and is still heavily timbered with hard-

woods and hemlocks, mainly the latter-named tree. Prominent among the hardwood species are sugar maple, birch, elm, oak, and some basswood. Inroads upon the forest are now being rapidly made by the lumber companies at Goodman and Wausaukee. There are one or two farms upon the type in the vicinity of the village of Goodman. (Pl. IV, fig. 2.)

The level of ground water in this soil is probably from 10 to 50 feet from the surface, and sufficient well water for domestic purposes can very generally be obtained from the drift overlying the hard crystalline rock. The water is excellent, being typical soft water.

The Coloma loam, as just stated is still a virgin soil, unopened to agriculture. The dense stand of hardwoods found upon it, however, is a good indicator of considerable natural fertility. The excessive quantity of stone in places is an objectional feature. On almost every section are areas too stony for successful cultivation, but such stony areas are generally small and can be conveniently devoted to wood lots or pasture lands, and most of the type is sufficiently free from stone to be used for farming.

All the general farm crops can be grown on this soil, but it is probably best adapted to potatoes, oats, rye, peas, clover, and grasses. It is a favorable type for dairying, and a system of agriculture built about dairying as a leading industry is probably the most promising. Corn for ensilage and also other forage crops can be grown successfully. By developing dairying as a leading industry, and giving some attention to sheep raising, the productiveness of the farms can be maintained or increased.

The hardier varieties of apples can undoubtedly be grown for home use, and all kinds of garden berries and vegetables can be produced.

No values can be given for cleared farm lands on this type. Unimproved cut-over lands containing little or no merchantable timber, are held at $5 to $15 an acre.

The following table gives the average results of mechanical analyses of the soil and subsoil of this type:

Mechanical analyses of Coloma loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
22723, 22725.....	Soil.....	0.4	3.5	5.5	9.4	19.9	52.2	8.6
22724, 22726.....	Subsoil.....	1.1	5.1	7.6	12.8	24.6	40.1	7.8

MUCK.

Muck consists of a mixture of organic matter with a relatively small though varying proportion of mineral materials. It has been formed in areas of deficient drainage where a rank vegetation flourished. The organic part of the soil represents the accumulated decaying remains of plants and the mineral portion the more or less finely comminuted rock particles carried into the depressions by streams or by the wind. The deposits are often many feet in depth.

The Muck is generally in a swampy condition. There are many such areas in Marinette County. They usually lie along the smaller streams, but occasionally form interstream areas of considerable extent.

Some of the wet lands along the streams are treeless and called "hay marshes" while other, generally overflow land, support a growth of swamp maple, alder, white birch, and water elm. Much of the marsh and swamp areas comprise soils ranging texturally from Muck to sandy loam, the determining factor in separating this type being lack of drainage rather than texture. When drained some of the areas of swamp will be practically the same as the surrounding type, while others will be more like true alluvial soil. Some of the overflow lands are very fertile and when cleared and drained will constitute the best soils on many farms. A few areas were cleared and used for wild hay.

In addition to the swamps along the rivers and small streams, there are numerous swamps of greatly varying size, over interstream areas, pactically all of which are covered with a more or less valuable growth of cedar, tamarack, or both. The largest of these forested swamps does not exceed 4 square miles in area,

and most of them could be drained, adding a large area to the valuable agricultural land and taxable resources of the county.

None of the heavy black Muck in the county is under cultivation, but when drained this type is valuable for truck crops, such as celery, onions, spinach, lettuce, and peppermint.

PEAT.

Most of the Peat in Marinette County is situated in the southeast corner adjacent to, or surrounded by, the Dunkirk fine sand. Locally the areas are called "peat bogs" or "hay marsh," to distinguish it from the swamps in which cedar or tamarack is always found. The true Peat is a level, usually treeless expanse, very wet in the spring and early summer, and supporting a rank growth of marsh grass, cat-tails, mosses, and other water-loving plants and shrubs.

The soil in these areas consists of organic matter in various stages of decomposition, and of varying depth, underlain by a medium to coarse grayish-white sand. The average depth of the organic material is about 2 feet. In places this covering has largely the character of Muck, but for the most part it is more accurately described as Peat, being a brownish or dark brown mass of partially rotted moss, leaves, and other vegetable remains of a spongy, coarse consistency.

Much greater progress has been made in developing this type than in the case of Muck, owing to the proximity of the former to the cities of Marinette and Peshtigo. About 2 miles west of Marinette a number of progressive farmers have formed a drainage district and have successfully drained a large area of Peat by digging a deep canal through it. Considerable difficulty has been experienced during the last year, however, owing to filling in of the ditches by sand, brought in by seepage waters from the sides. Diking or riprapping may have to be resorted to.

The State experiment station has had a cooperative station located on the Peat west of Marinette. Various experiments have been conducted there by the resident farmer, under direction of the station.

Where farmers have both the Peat and the sandy soils it is best to reserve the manure to be used on the sandy soil and ap-

ply wood ashes and phosphate fertilizers to the Peat, because the sandy soils are benefited by all the constituents, especially the nitrogen contained in the manure, while the Peat, rich in nitrogen, responds to the potash, phosphate, and lime contained in the ashes. The ashes can be obtained in considerable quantities from the mills in Marinette and Menominee.

ROCK OUTCROP.

There are a few local areas in Marinette County in which ledges of the underlying rock outcrop in sufficient number to make such areas practically worthless for agricultural purposes. These have been shown on the map by symbols but are included in the areas of other soil types. The principal areas of this character occur in Tp. 37, R. 21, Tp. 38, Rs. 20 and 21, and Tp. 37, R. 18, although there are several smaller areas in other townships in the northern part of the county. The material composing these outcrops is mostly red and gray granite, and to some extent greenstone.

In the areas mentioned above, the rock does not appear at the surface over the entire area, but does appear so frequently and is often so near the surface in the spaces between the actual outcrops, that little can ever be done with the land agriculturally. The only practical use is for forestry or pasturage. Outcropping ledges are by no means uncommon all over the area underlain by crystalline formations, which embrace approximately the northern three-fifths of the county, but except where indicated on the map, are so infrequent as to be practically negligible.

SUMMARY.

Marinette County is located in the northeastern part of Wisconsin, and has an area of 1,413 square miles.

The surface varies from nearly level plains to low undulating hills. The altitude adjacent to Green Bay is 580 feet, and in the northwestern part of the county about 1,500 to 1,600 feet. The drainage is through the Menominee and Peshtigo rivers.

The climate is rigorous in winter and warm in summer, the mean winter temperature being 15.7° F., and the mean

summer temperature 64.6° F. The average annual precipitation is 28 inches, about 20 inches for the growing season and 8 inches for the non-growing season.

The first settlement in Marinette County was made by the fur traders in 1791. The first farm was started in 1826. Agriculture, however, only began to be important in the period between 1870 and 1880.

The county was originally heavily forested with pine, hardwoods, and hemlock. Practically all the pine has been cut, but heavy stands of hardwoods and hemlock still remain in the northwestern part. A large part of the county is cut-over land.

In 1905 about 20 per cent of the county was laid out in farms, and 6.7 per cent of the county was improved land. In 1910, U. S. census, 24.2 per cent of the county was in farms, and 8.7 per cent of the land area of the county was improved. It is estimated that the land that will finally be improved is 70 to 75 per cent of the county. Agriculture, therefore, is still in its formative stage.

Up to very recently the manufacture of lumber products has been more important than agriculture. At present, however, agriculture is as important as manufacturing, and will probably be more important than manufacturing in the future.

The population of the county increased from 5,057 in 1875 to 33,810 in 1910. About one-half the population is on the farms and one-half in the villages and cities. Most of the population is native born. The foreign born are mainly from Canada, Germany, Sweden, Norway, Poland and Denmark.

The improved land increased from 16,989 acres in 1885 to 79,474 acres in 1910. The value of the farms in 1885 was less than $1,000,000 and in 1910 $6,489,590.

The county is well supplied with railroads and local markets. The city of Marinette, population 14,610 U. S. Census, 1910, is the county seat. A county agricultural school is maintained at Marinette. A State experimental farm, on sandy soil, is established at Crivitz.

The soils are of glacial and alluvial origin, derived from limestone, sandstone, and granite debris. Seven types of soil,

exclusive of Muck, Peat, and Rock outcrop or stony land, were mapped.

The Miami fine sandy loam is undulating land, and supported generally a strong growth of heavy hardwood and pine, most of which has been cut. It is the best soil in the county and suitable to all farm crops.

The Coloma loam, undulating and often stony land, is still forested with dense growth of hardwoods and hemlocks. Though practically undeveloped, it is a fertile soil, as indicted by its dense growth of timber.

The Coloma fine sandy loam is generally undulating to hilly land, and originally supported a mixed growth of pine and hard woods, mainly oaks. This type is especially well adapted to potatoes, corn, oats, rye, peas, and clover.

The Superior fine sand loam is relatively unimportant in extent, and consists of sand over a subsoil of red clay on level areas. It has about the same crop adaptations as the Coloma fine sandy loam.

The Dunkirk fine said is low, level sandy land, associated with Peat land within the area of the former Algonquin Lake between Marinette and Peshtigo.

The Coloma fine sand is hilly and undulating land, originally forested mainly with white and Norway pine, and some jack pine, while the Plainfield sand is level, and is known as the jack pine plain type.

The sandy soils—Dunkirk fine sand, Coloma fine sand, and Plainfield sand—are typical truck soils, but under present conditions should be devoted to general farming with oats, rye, corn, potatoes, and the soy bean as principal crops. Mammoth clover should be grown extensively in order to supply nitrogen and organic material to these sandy soils.

The Muck areas have not yet been brought under cultivation. The Peat west of Marinette has been cropped successfully where properly drained and fertilization by manure or wood ashes has been applied.

The rough land of the area, that which is too stony to be cultivated, should be devoted to forestry or to sheep raising.

All the soils of the area are given applications of barnyard

manure, but very little commercial fertilizer is used. Many of the soils, especially the sandy types, appear to be in an acid condition, and would be benefited by applications of lime.

Fruit growing, especially small fruits and bush fruits, might well be extended. Apples, adapted to the climate, do well on the hardwood types of soils, and with proper care have proven to be a profitable crop. Sugar beets are grown successfully on the Miami fine sandy loam.

Dairying and stock raising are important industries in the county on all soil types, and should be increased, not only for the money profit to be derived, but also as an important means in conjunction with proper crop rotation, including the plentiful growing of clover and the use of fertilizers, in developing a system of permanent agriculture.

A. Beach of Lake Superior, at line between Bayfield and Douglas counties. The cliff exposes red clay, containing boulders. The beach is sandy and shows much magnetite sand. The launch used in making the survey, is shown in the foreground.

B. Up-curve in beds of the Chequamegon sandstone, east side of Outer Island. These phenomena may be due either to folding, concretionary iron banding, or original deposition (see p. 30).

WISCONSIN GEOLOGICAL AND NATURAL HISTORY SURVEY
E. A. BIRGE, Director W. O. HOTCHKISS, State Geologist
BULLETIN NO. XXV SCIENTIFIC SERIES NO. 8

SANDSTONES OF THE WISCONSIN COAST OF LAKE SUPERIOR

BY
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MADISON, WIS.
PUBLISHED BY THE STATE
1912

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MAP

West End of Lake Superior. . . . . IN POCKET

INTRODUCTION

Purpose of the Investigation. The study made by the writer in 1910, the conclusions of which are set forth in this report, was to determine, so far as possible, the age, origin, and stratigraphic relations of the red sandstones of the Wisconsin coast of Lake Superior. These rocks are, so far as known, entirely devoid of organic remains. They were at an early day divided into two great groups. Of these the older is characteristically composed of grains which are mainly feldspars and fragments of igneous rocks, and the strata are nearly always considerably tilted. On the other hand, the upper and younger group is almost wholly quartz sandstone, and its beds are in general approximately horizontal.

Former investigators recognized that the lower group was a part of the Keweenawan series, but opinions differed as to its relation to the upper; some held that they were conformable, while others maintained that an unconformity existed, and that the upper group probably corresponded to the Cambrian of southern Wisconsin, or its conformable downward extension.

Summary of Results. One of the main results of the present study was the discovery of the fact that there is a conformable downward gradation from the upper quartz sandstone sediments into red shales and arkose sandstones which possess the same characters as the main body of the recognized Upper Keweenawan sediments. At one locality it was found that highly tilted feldspathic sediments almost unquestionably belonging to the Keweenawan series grade conformably upward into quartzose beds, lithologically indistinguishable from and probably continuous with the upper group. Furthermore, no evidence was discovered which tended to indicate that the two groups are unconformable. While the evidence is not positively conclusive, owing to the scarcity of outcrops, it is believed that the facts

warrant the conclusion that the sandstones form a single conformable series, so that what has heretofore been called the "Western sandstone" (here called the Bayfield group) is conformable with the underlying Upper Keweenawan arkose sediments (here called the Oronto group). The results of this work show that the contact of the upper, or Bayfield, group with the Middle Keweenawan traps is a fault. There is some evidence of unconformity at this contact. However, it is shown that if faulting took place prior to or during the deposition of the sandstone, the resulting local unconformity along the fault scarp would not demonstrate a great lapse of time between the deposition of the adjacent strata. Indeed, it seems certain that folding, faulting, and erosion went on during the deposition of the entire sandstone series, and that the upper beds therefore overlapped with slight unconformity upon the older strata of the same series. The difference in degree of folding of the two groups of sandstone is correlated with this fact and with the general structure of the region. Although no decisive opinion can at present be reached, it appears probable that both groups were deposited upon the land in a basin formed by the folding of the earlier Keweenawan rocks.

A detailed study of the lower sandstone group was not undertaken.

It seems probable that the so-called "red clastic series" which fills the continuation of the Lake Superior synclinal beneath the flat-lying Paleozoic rocks of Minnesota, is the continuation of the red sandstone of the Lake Superior coast. But, as no contact between these rocks and the recognized light-colored marine Upper Cambrian strata is known to be exposed, no definite opinion as to their relations can be formed. The results of this study, therefore, do not in any way affect the question of the age of the Keweenawan with reference to the Cambrian of the Mississippi valley. The evidence necessary to determine this question must be sought for along the extension of the upper sandstone group (Bayfield group) into Minnesota. However, the fact that the Bayfield group was involved in the profound deformations of the Keweenawan period, contrasts it sharply with the slightly disturbed strata of the recognized Cambrian of Wisconsin and Minnesota. It therefore appears from the

evidence at hand that the Bayfield group is more closely allied to the Algonkian than to the Cambrian.

The question of the equivalency of the Bayfield group to the supposed Cambrian sandstones of the east side of Keweenaw Point is not considered in this report. Both formations are barren of fossils and are separated by a wide area of older rocks, so that no correlation can be attempted with the evidence now at hand.

Method of Field Work. The region in which the formations under investigation are situated is very sparsely settled, and hence only accesible with considerable difficulty. A light launch was designed especially for the Survey by Dr. Kent T. Wood of Madison. This novel craft weighed about 250 pounds when ready to run, but could carry three times that weight. An efficient and reliable gasoline engine gave it a speed of over seven miles an hour on a fuel consumption of one gallon for twenty miles. The launch was very seaworthy, even more so than many larger craft, and possessed the great advantage of light weight, permitting it to be drawn up on the beach out of the way of the sudden and violent storms. (See frontispiece, Plate I, A). Little time was lost on account of high winds; and the engine never failed to start, even when the boat was nearly swamped while being launched into the breakers. A further advantage was, that the light draught permitted running close to the shore. All of the coast exposures were examined in this manner, landings being made on the rocks whenever anything of interest was observed. About a thousand miles were travelled on the lake and its tributary streams in the three months devoted to field work.

Maps. On shore, the geologist working on a rapid survey is obliged to contend with the fact that there are no accurate maps of the region. The township plats of the Land Survey, while much better than nothing, are quite inaccurate, especially in Iron County. Section corners, except a few recently marked, can only be found with trouble and delay, and few roads or fences follow the land division lines. It is difficult to keep one's location at all accurately when following the rocky bed of a winding stream. All rivers and creeks on which any exposures were reported by former geologists or by present inhabitants of

the district, were examined as thoroughly as the limited time available would permit and the importance of the formation seemed to warrant.

The base for the geological map is the general chart of the west end of Lake Superior, prepared by the U. S. Lake Survey.[1] This is accurate only so far as the navigation of large vessels requires. In shallow water and on shore it is unreliable. The township lines were adjusted to this base, the inland part of the map being based chiefly upon the plats of the U. S. Land Survey. The roads are corrected from observations by F. L. Musback of the Soils Division of the Geological and Natural History Survey and the writer, as well as from plats furnished by town clerks and others.

Acknowledgments. The writer was assisted by E. H. Toole of Baraboo, Wisconsin, then a student in the University of Wisconsin, who also spent some of his time in collecting plants and water life. For the last three weeks of the season, Thomas Turvill of Madison gratuitously contributed his services.

The work was carried on under the direction of W. O. Hotchkiss, State Geologist, and E. A. Birge, Director of the Wisconsin Geological and Natural History Survey. Much valuable information was obtained from F. L. Musback of the Soils Division of this Survey, who covered all the area east of Range 12 W. In the preparation of the report, most of those who have been interested in the question were consulted. The writer wishes to express his indebtedness to Prof. U. S. Grant of Northwestern University, Prof. F. F. Grout of the University of Minnesota, Prof. A. C. Lane, formerly State Geologist of Michigan, Prof. C. K. Leith of the University of Wisconsin, and Dr. Samuel Weidman of this Survey.

Acknowledgments are also due to Hon. S. S. Fifield, postmaster of Ashland, and his assistants, for much valuable aid at the beginning of the expedition; to Prof. J. A. Merrill of the Superior State Normal School for well-records and other help; to A. E. Appleyard, president of the Ashland Light, Power & Street Railway Co.; to J. E. Johnson, Jr., manager of the Lake Superior Iron and Chemical Co.; to F. N. Lang of Bayfield and

[1] U. S. Lake Survey Office, Detroit, Mich., Chart 96.

C. N. Edin of Dedham—the last three having furnished well-records; to the officers and men of the John Schroeder and J. S. Stearns lumber companies, and the Good Land Company of Ashland, for information and assistance; to William Foley of Ashland, to whose infomation is due the discovery of the important outcrops on Fish Creek; and to many others, too numerous to mention, who treated our party with great kindness and hospitality.

Expedition of 1912. In June, 1912, the writer spent a week in re-examining several important localities. A detailed plane table map was made of the important exposures on the South Fork of Fish Creek, near Ashland, and a careful but unsuccessful search was made for exposures between these and the known area of the Bayfield group to the north. References to the results of this expedition have been incorporated in the text. No observations were made which materially changed any of the opinions formed as a result of the earlier survey.

CHAPTER I

THE TOPOGRAPHY OF THE WISCONSIN COAST OF LAKE SUPERIOR.

General Statement. In order to arrive at a better understanding of the geology of the Wisconsin coast of Lake Superior, a brief review of the main topographic features of the district is desirable.[1] This region may be divided into the following more or less well-defined districts:

The Southern Highland, including the Penokee Range, the plateau south of it, and the trap hills immediately to the north.

The Trap Ranges of Douglas County and the north coast.

The Bayfield Ridge, including the Pine Barrens to the southwest.

The Apostle Islands.

[1] More detailed accounts of the topography and physiography will be found as follows:

Irving, R. D., Geology of Wisconsin, 1873-9, vol. III, pp. 60-211.

Sweet, E. T., Ibid, pp. 310-352.

Krey, J., Lake Superior and Mississippi Canal, House Doc. 330, 54th Congress, 1st Session, 1896.

Collie, G. L., Wisconsin Shore of Lake Superior, Bulletin Geological Society of America, vol. XII, 1901, p. 199.

Case, E. C., Wisconsin, Its Geology and Physical Geography, Milwaukee, 1907.

Martin, L., Geology of Lake Superior Region, Monographs U. S. Geological Survey, vol. LII, 1911, pp. 85-117.

The Western Plain.
The Eastern Plain.

The Southern Highland. The highest elevations occur at the southeastern corner of the area shown on the accompanying map and birds-eye view (Plate II, p. 8); but as seen from the lake this region because of its distance is not as impressive as some of the other features. The level skyline seen from the lake is formed by the southernmost ridge, sometimes known as the Gabbro Range, of Keweenawan traps, whose northward-dipping, steeply-inclined beds underlie the north slope of this highland. At its base is found a low escarpment, formerly known as the Copper Range, which marks the border of the traps where they are overlain by the sandstones of the lowlands to the north. The lower slopes are often heavily mantled with glacial drift, but at higher levels there appear bare ridges or hogbacks of rock. These culminate in the great escarpment, or Gabbro Range, which overlooks the longitudinal valley to the south, followed by the railway. This valley is underlain by slates, graywacke, and iron formation of Huronian age.

Beyond this, farther still to the south, rises the Penokee Range of slate, quartzite, and lean iron formation, the summits of which are some 1,200 feet above the lake or 1,800 feet above tide, exceeding but little the elevation of the trap ridge to the north. An abrupt slope on the south side of the Penokee Range leads down a hundred feet or more to the rolling upland underlain by Archean granites and metamorphic rocks. The streams having their sources in this area cross the ridges through deep gaps. The larger ones seldom follow the strike of the rocks for any great distance, though the strike determines the major lineaments of the country. The tumultuous descent of the streams usually ends in a high fall, where the soft sandstone is reached. Nearly all of these streams exhibit magnificent rock exposures, and outcrops are abundant throughout the Southern Highland district, only a portion of them being shown on the map.

The Trap Ranges: Douglas County. Stretching across Douglas County in the western part of the district, is a comparatively low and much broken ridge, or rather a series of ridges, known as the "Douglas Range," "Copper Range," or "South Range." Its summits do not extend much over 500 feet above

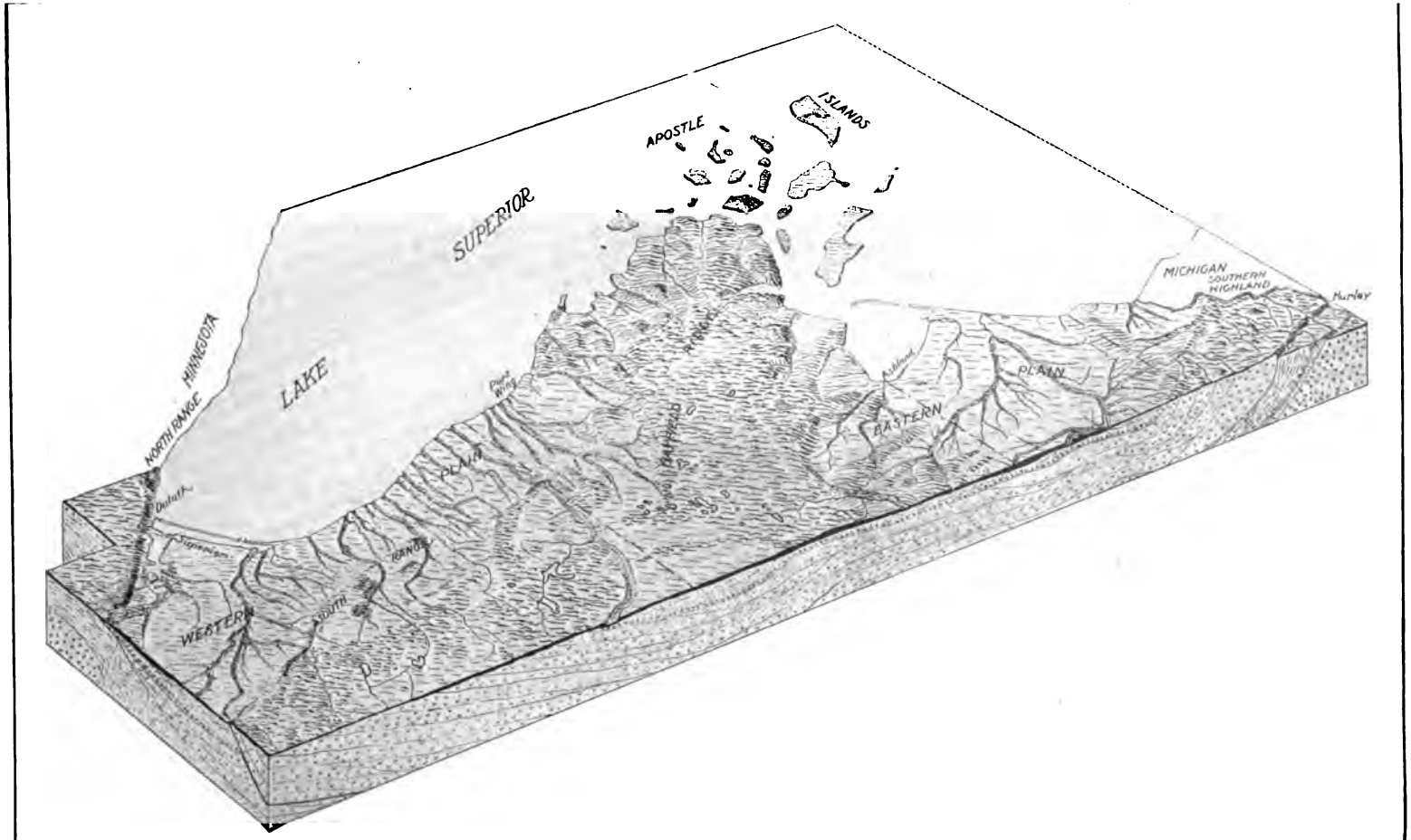
the lake, so that as seen from the coast it is not very striking. The southern slopes are rather gentle, but on the north is a descent of 50 to 300 feet to the plains which border the lake. This ridge is underlain by Keweenawan traps, moderately inclined to the southeast, and the escarpment marks the contact with the sandstones to the north. The streams cross through gaps and descend in falls to the lowlands.

North Range. Along the north coast in Minnesota occurs another range of similar rocks, also dipping to the southeast. It is higher than the South Range, and the serrated summits which are visible from the south coast on any clear day, form a very striking skyline. A few miles southwest of Duluth this range ends in a bold bluff about 450 feet in height. (See Duluth sheet, U. S. Geol. Survey, and Duluth plate, Geology of Minnesota, vol. IV, p. 566.)

The Bayfield Ridge. The broad peninsula which stretches out into the lake east of the Douglas Range, off the end of which lie the Apostle Islands, is for the greater part of its length the most conspicious topographic feature of the district. The average elevation of its summit is nearly 700 feet above the lake, or 1,300 feet above the sea. Topographically, it is a continuation of the Douglas Range and the high country to the south of it, but unlike the elevations previously described, the Bayfield Ridge so far as known consists wholly of drift. Except along the shore and a few of the deepest valleys, exposures of solid rock are absolutely wanting; and these are all of sandstone instead of igneous rocks.

The borders and the northeastern extremity of this ridge are cut up into ridges and isolated hills which have the appearance of land forms due to erosion. Up to a level of 500 to 550 feet above the lake are found terraces cut by the waves of former lakes held at these levels by the slowly retreating glaciers. These abandoned beaches run around the isolated hills and along the ridges, often producing the impression of rock escarpments. The slopes are cut by many deep ravines.

The summit of the Bayfield Ridge shows considerable areas of very rough, sandy, glacial moraine; the pits between the hummocks are among the largest in the state, being often over 150 feet in depth, and separated from one another by extremely nar-


APOSTLE
ISLANDS
SUPERIOR
LAKE
MINNESOTA
NORTH RANGE
Duluth
Superior
WESTERN
SOUTH
RANGE
PLAIN
Grand Rapids
Park Rapids
Ashland
EASTERN
PLAIN
MICHIGAN
SOUTHERN
HIGHLAND
Hurley

row sharp ridges. Towards the southwest, this sandy country, called the "Pine Barrens," is of less relief. A striking feature of this entire upland is the absence of streams; lakes are found, however, the water being prevented from seeping away by the occurrence of a clay layer at a moderate depth. The Barrens present a most desolate appearance, now that all the timber has been cut. Only a few burnt stubs are left standing out mournfully above the sweet fern, scrub oaks, and low second growth.

The Apostle Islands. If we follow the Bayfield Ridge to the northeast, where it is broken up into separate hills, we will find that the same sort of topography extends beneath the surface of the lake, the summits of the hills forming the famous Apostle Islands. These islands were so named because once they were erroneously supposed to be twelve in number. Twenty-two islands now exist, one having succumbed to the attacks of the waves, and another having been cut in two since the coming of the first explorers. A study of the contours of the lake bottom (see map) and bird's eye view (Plate II, p. 8) shows the relation of the group to the topography of the mainland. There are a number of shoals which a slight fall of the water level would make into islands, and the same water stage would join some of the present islands to the mainland. On the other hand, the rise of the waters would submerge several islands and surround some of the hills near the coast. With the gradual lowering of the lake level since glacial times, there has been a progressive change in the composition of the Apostle group. The mainland has steadily been extended to the northeast, while lower and lower shoals have in turn become islands.

The present islands range in size from Madeline, twelve and one-half miles in length, to mere rocks, like Little Manitou. They vary from a height which is barely above the storm waves, to an elevation of 480 feet on Oak Island. Outer, Stockton, and Bear Islands are the only others to exceed 100 feet in altitude, most being flat and low. The higher ones are terraced by abandoned beaches, none of which, so far as known, exposes any rock.

The waves of the present level have cut deeper into the land than at any other stage, with the possible exception of the highest (see p. 13). Their work may be seen in the cliffs, bars, and beaches.

The cutting due to the present stage of the lake has exposed cliffs of the red sandstone. They do not exceed 60 feet in height, and are almost always capped with broken rock and drift. All are lined at the foot with fallen blocks, which, however, break up rapidly, so that there is little sandstone shingle. These fallen fragments, submerged ledges which sometimes form dangerous reefs, and the clean, reddish, sharp sands derived from their breaking up, may all be seen through the clear, cold, greenish waters of the lake. In thin-bedded layers only, have the waves worn any striking sea caves. The best are on Devils Island and near Squaw Bay to the southwest; but small ones, as well as deep coves along joint planes, are seen on the eastern end of Stockton Island and at a few other points (see Plates I, B, frontispiece; IV, p. 30; V, p. 40; XXIII A, p. 94).

A large portion of the shore line is drift. The materials exposed in the cliffs are mainly stony red clay, although the tendency of this material to slump down the bank gives one an undue idea of its abundance. Sandy till, gravel, and clean white or reddish sands are probably more abundant. So far as the writer's observations go, they underlie the red clay or clay till. Sand beaches are very common but are usually thickly strewn with boulders washed out of the drift. Huge fields of these, thickly paving the bottom, are frequently seen. Much of the ground marked as "rocky" on the chart is of this character. Spits of clear sand are found on the sides of the islands toward the mainland, that is, on the most sheltered side. These spits have usually been built out from both sides and often enclose a pond or swamp. At the outer ends is usually a rapid descent into deep water. Some seem to be now wasting away, as on Madeline Island, in which case they extend lakeward as shoals. Many bays have been cut off by beaches and in some cases the action of the waves has joined two rocky islands into one.[1]

The islands are nearly all densely wooded, some magnificent forest being seen in places. Hemlock, balsam, birch, and maple predominate. The dark foliage, together with the prevailing red

[1] The bar connecting Sand Island and the mainland does not appear to be wholly wave work. Cf. Collie, G. L., Wisconsin Shore of Lake Superior, Bull. Geol. Soc. Amer., vol. 12, 1901, p. 199.

color of the drift and rocky shores, give the islands a rather somber and forbidding appearance.

Permanent settlement is confined to Sand and Madeline Islands, but light-houses and fishing stations are found on most of the group. Now that the quarries are abandoned, sand is the only geological product (see p. 27). Several dredges take this material to Duluth from the spit on Oak Island.

The Western Plain. West from the little settlement at Herbster on the northwest side of the Bayfield peninsula, the main body of the great Bayfield Ridge leaves the coast. To the southwest stretches a broad sloping plain, broken at first by a few isolated hills like those near the end of the headland. For the most part of its length it is bounded on the southeast by the escarpment of the Douglas or South Range; but in some places where this is ill defined, it extends across the line of the traps up to the highest abandoned shore line which is found to the south upon the Pine Barrens. Near Superior the plain broadens, being bounded on the north by the North or Minnesota Range.

The surface of the plain is not level but slopes toward the lake at the rate of nearly fifty feet per mile; the inclination southwest of Superior, measured along the line of the axis of the lake basin, is much less.

No prominent beach terraces can be seen on the surface of this plain, which is broken only by slight marshy sags. It is dissected by narrow, steep-sided valleys cut by the numerous streams in the underlying soft red clay and fine sand. These valleys range from a few feet to over 100 feet in depth, with a flat bottom sometimes more than a quarter of a mile in width. The abundance of streams contrasts sharply with their rarity in the regions of porous sandy subsoil.

The lake shore (Plate I, A, frontispiece) is a steep cliff except at the mouths of rivers, where clean sand beaches occur. At the foot of this cliff is usually a stony beach. In the valleys of the streams and in the shore cliff are found infrequent exposures of the red sandstone underlying the drift.

At the head of the lake, southwest from Superior, is a very irregular shore line caused by the drowning of the valleys by the waters of the lake (see p. 13). Two long sandy beach ridges

known as Minnesota and Wisconsin points, cross the end of the lake, enclosing Superior and St. Louis bays.

The Eastern Plain. In northern Ashland County, between the Southern Highland and the Bayfield Ridge, is a plain which differs only from the Western Plain in being more thickly dotted with sandy ridges and hills. The slope of this plain is about ten feet per mile in the middle, but it is steeper where it laps up against the highlands to the south. To the northwest it merges into the Bayfield Ridge, spurs of which extend out between the streams. The surface of the plain is cut by steep-sided valleys, some of which are over a half mile in width.

Between the irregular shore line of the Bayfield peninsula and the Apostle Islands, and the point where the Southern Highland strikes the lake at Clinton Point in Iron County, stretches a smooth sweep of sand beach. Its western extremity, known as Chequamegon Point and Long Island, separates a great depression in the shore line from the open lake; this is Chequamegon Bay. For the most part this bay is very shallow, especially on the east side where the bottom is a continuation of the low marshy country behind the beach ridge north of Odanah. The small break between the point and the island is called the Sand Cut and is said to have been first formed by a great storm in 1872.[1] As this low ridge alone protects the large bay from the violent northeast winds, it does not form a good harbor. A breakwater has been found necessary at Ashland.

Outline of Surficial Geology. The subject of the Pleistocene geology of this district is at present under investigation by Mr. Frank Leverett of the U. S. Geological Survey, and the Soils Division of this Survey is engaged in a study of the soils and agricultural conditions. The U. S. Bureau of Soils has published two reports upon the part of the area west from Range 12 West.[2] Although little time was given by the writer to the subject of the surface geology, a brief summary of its main points will be given.

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[1] Irving, R. D., Geology of Wisconsin, 1873–9, vol. III, p. 71. Collie, G. L., Wisconsin Shore of Lake Superior, Bull. Geol. Soc. Amer., vol. 12, 1901, p. 199.

[2] U. S. Dept. of Agriculture, Soil Surveys of the Carlton and Superior Areas, Field Operations, Bureau of Soils, 1904, 1905.

Deposits of Pleistocene and Recent age form a nearly continuous mantle, which with comparatively few exceptions conceals the hard rocks throughout the whole of the area. Only the Southern Highland, the Douglas Range, and the lake cliffs show many rock outcrops. The drift deposits range in thickness from nothing to nearly 600 feet. The maximum thickness is attained in buried valleys under the St. Louis River at Superior and south of Ashland, and in the Bayfield Moraine.

The materials of the drift are till, clay, sand, and gravel, nearly always of red or yellow color. Water-laid deposits are more abundant than ice-laid material. The deeply weathered character of the rocks at most points suggests that glacial erosion was not active, at least toward the end of the ice epoch. Far more detailed observations than any heretofore made will be needed before the complex history of these deposits is made known. The question of the origin of the west end of Lake Superior is considered on p. 95.

At one stage in the retreat of the last ice, the waters of Lake Superior[1] stood so high that they overflowed through a low col at the head of the Brule River, at an elevation of some 500 feet above the present level, into Lake St. Croix in Douglas County. This is known as the Lake Duluth stage. The outlets of the lower stages, whose beaches do not indicate as long a duration as that of Lake Duluth, are not yet definitely known. At the present time a slow tilting of the region along a northwest-southeast axis is going on, which is causing the water to advance upon the land at most places within this area, the movement probably being at a maximum in the vicinity of Superior. The large amount of post-glacial erosion as shown by the deep stream valleys, is due to the impervious character of the soft red clay which forms the surface of a large part of the area.

[1] A brief summary of this subject will be found in an article by Frank Leverett, Outline of History of the Great Lakes, 12th report of the Michigan Acad. of Sci., 1910, p. 19.

CHAPTER II

PREVIOUS INVESTIGATIONS

Owen, 1847–50. The first competent geologists to make a careful examination of the Wisconsin coast of Lake Superior were David D. Owen and his assistants, J. G. Norwood, A. Randall, and C. Whittlesey.[1] Their explorations were made before the completion of the land survey, while the country was still known as the Chippewa Land District. This survey was made for economic purposes, since the question of the disposal of the public mineral lands was then a vexed one, as it is today. Owen was commissioned by the Treasury Department to classify the public lands with regard to their mineral and agricultural value. Taking into consideration the state of the country, and the progress of the science of geology at that time, this piece of work was remarkably accurate and thorough. The party explored all of the coast and most of the streams, mainly during the seasons of 1847 and 1848.

In his first report, in 1847, Owen concluded, chiefly from lithological evidence, that the Lake Superior sandstones were post-Carboniferous, for he regarded all the igneous rocks as intruded at a geologically recent date. However, in his final report of 1852 he withdrew this statement and advanced the

[1] For full titles with annotations refer to bibliography, p. 21.

Owen, D. D., Report of a Geological Reconnaissance of the Chippewa Land District, Senate Doc., 30th Cong., 1st Sess., 1847.

Report of a Geological Survey of Wisconsin, Iowa, and Minnesota, etc. Philadelphia, 1852.

hypothesis, based on exposures along St. Croix river, that it was a downward continuation of the Mississippi valley Cambrian He drew no distinction between the different kinds of sandstone upon the lake. Owen also noted the gentle southeasterly dip of the strata in the Apostle Islands, and along the south coast, a fact which has escaped many subsequent observers.

Whittlesey, 1860. In 1860 Charles Whittlesey explored the eastern part of this district but owing to the abolition of the Wisconsin Geological Survey at the time of the war, his report was never published. An article entitled "The Penokee Mineral Range" was published by him in 1863; this gives a brief description of the district.[1]

Irving, 1873-78. Prof. Roland D. Irving was the first geologist to study the complex geology of the Lake Superior region in the light of modern knowledge. The eastern half of the district was surveyed under the personal direction of Prof. Irving, while the western portion was covered by E. T. Sweet. All of the known outcrops with the exception of those of Fish Creek and Oronto River were visited. The main fault of this excellent piece of work is the failure to show the outcrops upon the final maps. This deficiency is supplied in part from the text of the final and annual reports; but owing to the destruction of the field notes by fire, it is a serious handicap to the geologist who attempts to retrace the work.

Irving[2] naturally spent most of the short time at his disposal in a study of the Penokee Iron District, so that the sandstones received scant attention. Only a portion of the outcrop on Clinton Point, Iron County, was visited; and as the inclined beds were not seen, the rock was correlated with the horizontal sand-

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[1] Whittlesey, Charles, The Penokee Mineral Range, Proc. Boston Soc. of Nat. Hist., vol. 9, pp. 235–44, 1863; reprint in part, Geol. of Wis., 1873–9, vol. III, p. 216.

[2] Irving, R. D., Some Points in the Geology of Northern Wisconsin, Wis. Acad. of Sci. Trans., vol. 2, 1874, pp. 107–119.

—— On the Age of the Copper-Bearing Rocks of Lake Superior, etc., Amer. Jour. Sci. and Arts, vol. 8, 1874, pp. 46–56.

—— Geol. of Wis., 1873–9, vol. III, pp. 1 24, 53–238.

—— Copper-Bearing Rocks of Lake Superior, Mon. U. S. Geol. Survey, vol. V, 1883; see references below.

stones of the islands. In his preliminary articles, Irving mentioned horizontal sandstone and shale on Silver Creek near the modern village of High Bridge, Ashland County; but in his later monograph he stated that this was an error of Lapham's.[1]

In the Geology of Wisconsin, Irving affirmed that there were two great unconformable groups of sandstones. This statement was based first upon the horizontal attitude of the Bayfield sandstone group; second, upon the supposed unconformity complicated by slight faulting along the north edge of the Douglas Range; and third, upon the supposed equivalence shown by lithologic and structural similarity of the upper group to the Cambrian (Eastern, now Jacobsville) sandstone of Michigan. Therefore the Bayfield group (called Western by Irving) was assigned to that period. Irving was of the opinion that the Bayfield Ridge was a continuation of the Douglas Trap Range, although he recognized its morainic character.

Sweet, 1873-77. In 1873, 1875, and 1877, E. T. Sweet made his examinations of this area under Irving's direction. In the last year he made a trip along the south coast of Lake Superior from Ashland to Superior in the short space of two weeks.[2] Sweet was unable to understand the contacts of the traps and sandstones along the Douglas Range and so wisely confined himself to the statement that the sandstone was the younger. On Middle River he mistook the horizontal joints for bedding.

Irving, 1881. After further field work outside of Wisconsin, Irving completed a report upon the Copper Bearing Rocks of Lake Superior.[3] Although in this work Irving definitely asserted the existence of a concealed unconformity between the Bayfield and Oronto groups, he conceded that on structural grounds there was no reason to separate this upper group (called

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[1] Irving, R. D., Copper-Bearing Rocks of Lake Superior, Mon. U. S. Geol. Survey, vol. V, 1883, p. 411.

[2] Sweet, E. T., Some notes on the Geology of Northern Wisconsin, Wis. Acad. of Sci. Trans. vol. 3, 1876, pp. 40–55.

—— Ann. Rept. Wis. Geol. Survey, 1877, p. 4.

—— Geol. of Wis., 1873-9, vol. III, pp. 305–362.

[3] Irving, R. D., Copper-Bearing Rocks of Lake Superior, Mon. U. S. Geol. Survey, vol. V, 1883.

by him Western Lake Superior sandstone) from the underlying feldspathic rocks, since both should be horizontal in the vicinity of the Apostle Islands.[1]

Winchell, 1872-99. The work of the Geological and Natural History Survey of Minnesota was carried on within this area by N. H. Winchell. The final report was published in 1899[2] together with rather large scale maps showing 50 foot contours. Unfortunately these maps do not show outcrops, so that it is often difficult to see the basis of the distinction between the areas mapped as drift and those where the underlying formations are shown. Moreover, there are several serious errors in the drafting of the sheets covering the vicinity of Duluth.

Local details were published from time to time in the annual reports, and in 1895 Winchell published two articles which deserve especial attention.[3] These were of a distinctly controversial nature but many of the points were essentially sound. He described the conglomerates of the St. Louis River and divided them into two parts. The lower quartz pebble conglomerate he placed at the base of the Keweenawan, and the remainder. which contains trap pebbles, as contemporaneous with the last eruptions. This involves the assumption that an unconformity exists within the space of a few feet where the exposure happens to be covered by debris. He correctly argued that the mere presence of trap pebbles in a conglomerate does not imply a post-Keweenawan age, since such pebbles are found in all Keweenawan detrital rocks. In other words, folding and erosion must have gone on simultaneously with the deposition of sediments in other places. Winchell also threw some doubt upon the unconformity supposed by Irving to exist along the Douglas Range, suggesting that some of the conglomerate might be faulted up from lower horizons. In the second article entitled, "A Rational View of the Keweenawan," Winchell formulated the following series of objections to Irving's view as to the unconformity of the two sandstone groups. Although his object was to demon-

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[1] Irving, R. D., Ibid, pp. 154, 258, 365, 410, plate XXVIII.

[2] Winchell, N. H., Geology of Minnesota, 1872–99, vol. IV, pp. 1–24, 212–225, 550–580.

[3] Winchell, N. H., Crucial Points in the Geology of the Lake Superior Region, Amer. Geologist, 1895, vol. 16, pp. 75, 150.

strate that the entire Keweenawan was of Cambrian age, a question not considered by the present writer, it is worth while to quote these objections:

There is no permanent petrographic distinction between them [the two sandstone groups]. The red shale and red sandstone, which are said to prevail in the tilted beds [Oronto group], are found in great volume in the lower portion of the horizontal beds [Bayfield group]. This may be seen by consulting the sections of the horizontal beds [along St. Louis River] * * *.

The tilted beds [Oronto group] are sometimes horizontal, and the horizontal beds [Bayfield group] are sometimes tilted at high angles. [The author did not state the localities where this paradox is true.]

The top of the Keweenawan sandstones has never been observed.

The bottom of the overlying [Bayfield] sandstones has never been observed except where, by regional subsidence, it is non-conformable upon the tilted traps or the older rocks. [It may be noted that all known contacts with the traps are complicated by faulting.]

In various places the horizontal sandstone [of the Mississippi valley], even some of the higher magnesian limestones [no such case is known to the writer], have been seen non-conformable on the traps of the lower portion of the Keweenawan, indicating a progressive subsidence after the tilting of the traps.

The non-conformable contact which is assumed to have taken place between the base of the horizontal sandstones [Bayfield group] and the Keweenawan tilted sandstones [Oronto group] has never been observed.

The whole region in which this question centers is one of disturbance and eruptive action. Even since some of the horizontal sandstones were deposited there have been such movements [along the Douglas and Keweenaw Point faults] that the sandstones are broken and thrust in various attitudes in their relation to the trap.

The shortest observed interval between the horizontal and the tilted sandstones within which such nonconformity must exist, if it exist at all, is four miles, viz., between Montreal River and Clinton Point.[1]

If it were to be affirmed that there is no such non-conformable contact between these sandstones, the statement could not be disproved by any known facts.

If the statement were to be made that the upper part of the Ke-

[1] The sandstones of Clinton Point are not horizontal and do not belong to the Bayfield group (see p. 55).

weenawan [Oronto] sandstones passes conformably into the horizontal * * * [Bayfield] sandstones * * * in all places where they are in contact, such statement could not be disproved by any known facts, but would be in harmony with all that is known of the formation.

A figure given by Winchell showing a generalized section from Montreal River to Clinton Point may be mentioned, for the fact that it shows horizontal sandstone on Silver Creek in Ashland County, indicating that the author had overlooked Irving's denial of the existence of such a formation (see p. 16).

In his final report of 1899, Winchell expressed his opinion, based on the boring at Short Line Park near Duluth, that the sandstone of St. Louis River was deposited contemporaneously with the later igneous eruptions, the gradual dying out of which "rendered the sandstone more and more siliceous," so that "the upper strata are almost free from the shaley, red sediment which characterizes the lower portion." It was also stated that the sandstones here found are conformable beneath those of known Upper Cambrian age in the Mississippi valley. This conclusion was apparently based, although the evidence is nowhere clearly exposed, upon the apparent areal connection of the sandstones of the Lake Superior and Mississippi basins. The results of deep drilling at Stillwater[1] and other points in southeastern Minnesota showing a thick red sandstone series beneath the horizontal Cambrian, were also cited as supporting the contention that there was a complete and conformable transition between the Upper Cambrian and the Keweenawan traps.

Grant, 1899-1900. In 1899 Professor U. S. Grant of Northwestern University commenced a study of the Keweenawan traps of Wisconsin which were then being prospected for copper, as they have been at intervals of thirty or forty years ever since first discovered. After a slight amount of work in 1900 the survey was discontinued and the notes were never published in full. Much of this valuable material has been made use of by the writer for the first time.[2]

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[1] Winchell, N. H., Natural Gas in Minnesota. Minn. Geol. & Nat. Hist. Survey, Bull. V, 1889, p. 25.

[2] Grant, U. S., Preliminary Report on Copper-Bearing Rocks of Douglas County, Wis. Geol. and Nat. Hist. Survey, Bull. VI, 1900, 2nd ed. 1901.

In his report Grant did not touch upon the age of the sandstones, but in a later paper[1] he described the contacts which occur within the area he studied. He recognized the great amount of faulting which has taken place since the deposition of the sandstone, as shown by the fold on Middle River. At this place he perceived the true bedding, but assumed that the structure was anticlinal as he did not observe the ripple marks which conclusively demonstrate the overturning of the strata. He saw that the great Douglas fault was of the thrust type although he showed it as vertical on his structure sections. The evidence with regard to the unconformity along this fault he declared to be inconclusive.

Collie, 1900. In 1900 Prof. G. L. Collie of Beloit College, visited the region about Bayfield and made some steamer trips through the Apostle Islands. A paper[2] published by him describes mainly the physiography of the region. His observations of the Lake Superior sandstones were very meager, while the theoretical conclusions as to the geological history of the region are for the most part based upon misconceptions of the facts.

Hall, 1901-08. In 1901 Prof. C. W. Hall of the University of Minnesota described the Keweenawan area of the eastern part of that state.[3] Evidence was cited to show that the great fault of Douglas County extends far into Minnesota, but the sections are drawn on such an exaggerated vertical scale that the true relations are confused.

In 1908, Hall prepared a paper discussing the great series of red sandstones and shales which drill holes have discovered beneath the exposed Paleozoic rocks of southern Minnesota. These he stated to be conformable beneath the later sediments and to represent a transition between the Paleozoic and Algon-

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[1] Grant, U. S., Junction of Lake Superior Sandstone and Keweenawan Traps in Wisconsin, Bull. Geol. Soc. Amer., vol. 13, 1902, p. 6.

[2] Collie, G. L., Wisconsin Shore of Lake Superior, Bull. Geol. Soc. Amer., vol. 12, 1901, p. 199.

[3] Hall, C. W., Keweenawan Area of Eastern Minnesota, Bull. Geol. Soc. Amer., vol. 12, 1901, p. 313.

kian rocks. Unfortunately this paper was never published, an abstract only appearing in Science.[1]

Lane, 1908. In 1908 Professors A. C. Lane, then state geologist of Michigan, and C. K. Leith and Lawrence Martin of the University of Wisconsin, visited Clinton Point and parts of Montreal and Oronto rivers. They first observed some of the inclined beds at the former locality, Professor Lane giving it as his opinion that they are conformable upon the formations seen to the southeast.[2] It was suggested that a fault parallel to that on Keweenaw Point might pass through the belt of no expoures found on Montreal River and thus give an apparent thickness of sandstone much in excess of the fact.

Grout, 1910. The work of Professor Hall in Minnesota has been carried further by Professor F. F. Grout of the University of Minnesota. Writing in 1910, he gave a summary of the recent work.[3] He expressed some doubt as to the correlation of the sandstones north of the Douglas fault with the fossiliferous series of the St. Croix valley which overlie the tilted traps with evident unconformity. The areal connection is moreover doubted since a wide drift-covered interval occurs between the two areas of sandstone.

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[1] Hall, C. W., The Red Sandstone Series of Southeastern Minnesota, Abstract. Science, vol. 27, 1908, p. 722.

[2] Lane, A. C. & Seaman, A. E., The Geological Section of Michigan. Rept. State Board of Geol. Survey of Michigan for 1908, p. 23. A brief reprint is found in Journal of Geology, vol. 15, 1907, p. 680.

[3] Grout, F. F., Contribution to the Petrography of the Keweenawan, Journ. Geol., vol. 18, 1910, p. 633.

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CHAPTER III

THE BAYFIELD SANDSTONE GROUP

Limits of the Group. The sandstones found along the Wisconsin coast of Lake Superior have long been divided into two groups. It is possible to draw a fairly definite line at the base of the prevailing quartz sandstones known as the Bayfield group, separating them from the underlying arkose sandstones and red shales which will hereafter be termed the Oronto group and which will be described in Chapter IV. The Bayfield group was formerly known as the Western Lake Superior sandstone. Because the correlation with the Lake Superior sandstone group of Michigan is uncertain, it seemed best to give the rocks in Wisconsin a new name.

Areal Extent. The Bayfield group is the highest rock formation of the area studied. It is the uppermost rock of all of the coast and islands from the mouth of Fish Creek at the head of Chequamegon Bay to the west line of the state; inland it is bounded by the Douglas Trap Range so that it underlies all of the Western Plain; how much of the Bayfield Ridge is underlain by sandstone is unknown on account of the heavy drift. So far as known, it never rises more than about 400 feet above the lake. The strata are, over most of this area, gently inclined to the southeast at low angles with a maximum of about five degrees. Apparently this dip decreases towards the southeast. Locally considerable folds are found (see p. 62), which bring to the surface rocks believed to belong to the underlying Oronto group. The Bayfield group extends into Minnesota and may possibly run

beneath the Upper Cambrian sandstones, but its relations to them are as yet unknown.

Subdivisions. The present study has shown that the Bayfield group as seen in Wisconsin may be divided into the following formations, beginning at the top;

	Approximate thickness
Chequamegon Sandstone. Red and white sandstone composed predominantly of quartz grains, with thin lenticular beds of red sandy shale	1,000 feet
Devils Island Sandstone. Pink and white pure quartz sandstone with abundant ripple marks	300
Orienta Sandstone. Like the Chequamegon in its upper part, but containing more feldspar grains especially towards the base	3,000
Total thickness, about	4,300 feet

Composition. Although predominantly a red sandstone, the Bayfield group is not wholly of that color. In many beds, and throughout most of the Devils Island formation, lighter colors prevail, ranging from pink, through yellow and light brown to gray and white. The very dark red "brownstone," widely known as a building stone, comprises only a small part of the group.

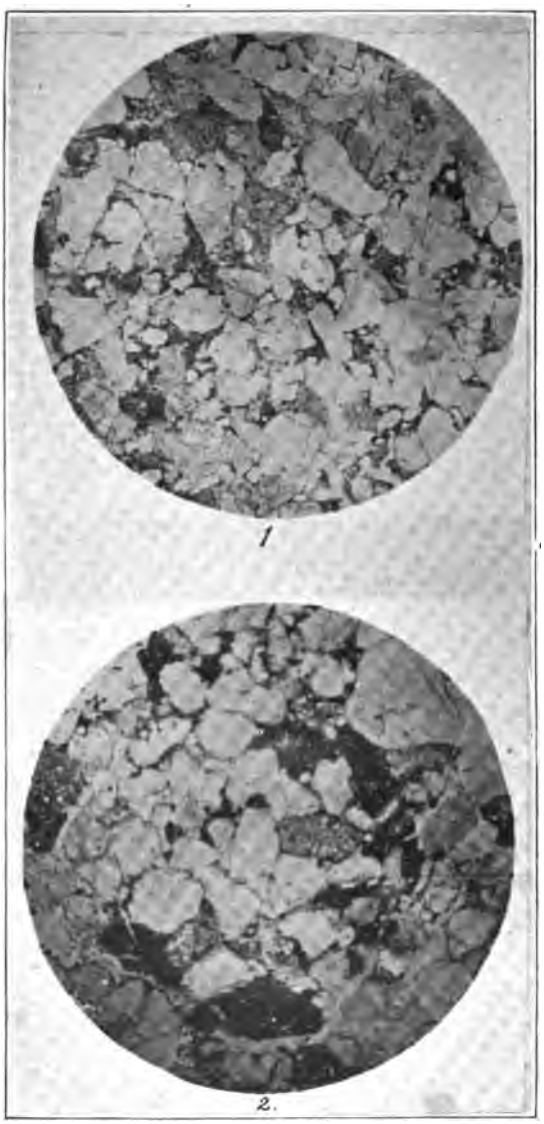
In size of grain the rocks vary from coarse pebbly grits down to shales, although very little fine clay occurs. (See Plates III, p. 26, and VI, p. 44). The coarse grits[1] are usually the lightest colored beds, and the thin bedded fine grained layers are usually the darkest in tint. The size of grain often varies very rapidly, but is usually coarsest near to bedding planes. The cement is generally quartz; the iron oxide, even where abundant, not being important as a cementing material. The iron usually coats the surfaces of the grains. Crystal faces due to enlargement of quartz grains, which are often so conspicuous in the sandstones of southern Wisconsin, are seldom observed. Enlargements of grains are nevertheless common but are nearly always quite irregular in form. The degree of rounding of the grains is

[1] In the use of the term "grit", the writer returns to its original meaning, a rock intermediate between sandstone and conglomerate.

PHOTOMICROGRAPHS IN ORDINARY LIGHT, MAGNIFIED 12 DIAMETERS. (Buckley, Bull. IV, Plate LXV).

A

B



A. Chequamegon sandstone from quarry at Houghton, Bayfield County (specimen 4719). The light-colored grains, averaging .35 mm. in diameter, are quartz, and show irregular secondary enlargements, which have accentuated their angularity. The gray grains are mainly somewhat decomposed feldspars, and the black areas are ferric oxide.

B. Chequamegon sandstone from quarry on Basswood Island (specimen 4714). In this section, the grains are somewhat more rounded than in A. Feldspar is not as abundant. The grains run up to .40 mm. in diameter.

variable, the best rounded grains being those of the Devils Island formation, while in the other formations the grains are usually subangular.[1] They contrast sharply with the smooth grains of the sandstones in southern Wisconsin (see p. 101).

The materials of the sandstones of the Bayfield group are in order of abundance: quartz, feldspars (both orthoclase and plagioclase), micas, iron oxides (both magnetite and limonite), chert, and ferromagnesian minerals. Often the materials other than quartz comprise nearly one-fourth of the rock. Most of these minerals are end products of weathering, so that the rock is very resistant to the action of the atmosphere. The feldspars, however, are nearly always somewhat decomposed, and in the more porous sandstones have often been weathered into little specks of white kaolin. It appears probable that a large part of the decomposition has taken place since the deposition of the rock, since otherwise the forms of the grains would not have been preserved so perfectly. Sometimes sands largely composed of magnetite grains occur. The Devils Island formation is an exception to the most part of the group in being nearly pure quartz sandstone, of medium to fine grain.

The following chemical analyses confirm the results obtained by the examination of thin sections (Plates III, p. 26, and VI, p. 44). The amount of feldspar is considerable and appears to be greater in the lower members of the group.

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[1] Irving, R. D., Geol. of Wisconsin, 1873–79, vol. III, p. 207.

Buckley, E. R., Building and Ornamental Stones of Wisconsin, Wis. Geol. and Nat. Hist. Survey, Bull. IV, p. 172.

Note: It is this angularity of the grains which makes the sands derived from the sandstone valuable for concrete. Lake sands washed from the drift, like those of Minnesota Point, are much more rounded and hence less desirable. (See p. 11.)

ANALYSES OF SANDSTONES OF THE BAYFIELD GROUP[1]

CHEQUAMEGON SANDSTONE

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	H_2O	Total
Locality										
1. Houghton	86.57	8.43	1.55	.....	.....	2.36	.67	T	.....	99.58%
2. Basswood Id.	87.02	7.17	3.91	.11	.06	1.43	.22	.....	T	99.92%
3. Basswood Id.	89.76	.....	.....	not	given	.....	.....	.....	.....	.....
4. Hermit Id.	91.64	.....	.....	not	given	.....	.....	.....	.....	.....
5. Madeline Id	93.50	3.90	(Ca,	MgO	O_3 -	1.00)	.....	.....	.....	98.40

ORIENTA SANDSTONE

6. Port Wing	89.33	6.05	1.41	T	T	2.12	.59	.....	.....	99.50
7. Siskowit Pt.	90.86	4.76	1 58	.15	.59	1 06	.45	.....	.....	99 45
8. Eagle Id.	84.13	... ..	.....	not	given	.....	.....	.....	.....	.....

Shale Beds. Small lenticular beds of shale, seldom over five feet in thickness, are found throughout the Chequamegon and Orienta sandstones. These are almost wholly of a sandy, micaceous character, little fine clay being found. In color they are usually the darkest parts of the rock, being a deep red tint, but are almost always streaked or spotted with yellow or white; less commonly, gray and green sandy shales are found. A very frequent accompaniment of these beds is a few inches of yellowish, coarse, and often pebbly sandstone above or below, or on both sides of the red bed. Sometimes pebbles occur in the shale itself. The shale beds are most common in hollows or troughs in the bedding, less often on inclined bedding planes (Fig. 1). Their horizontal extent is always small; they either pinch out or grade into thin bedded sandstone or curve up so that the layers are cut off by the overlying sandstone bed.

[1] Nos. 2, 3, 4 and 8 by E. T. Sweet, Geol. of Wis., vol. III, p. 208. Nos. 1 and 6 by W. W. Daniells, Wis. Geol. and Nat. Hist. Survey, Bull. IV, p. 420. No. 7, Geol. of Minnesota, vol. I, pp. 200, 202. No 5, by J. G. Norwood, Chippewa Land District, 1847, p. 56; Geol. Survey of Wis., etc., 1852, p. 188.

Bedding. As a whole, the Bayfield group is very irregularly bedded, in contrast to the even bedded calcareous sandstones of southern Wisconsin. This fact makes it hard to describe the features satisfactorily. The individual beds range in thickness from a fraction of an inch to over twenty feet, but within these massive beds are minor bedding planes which are more evident on natural exposures than in the quarries. The

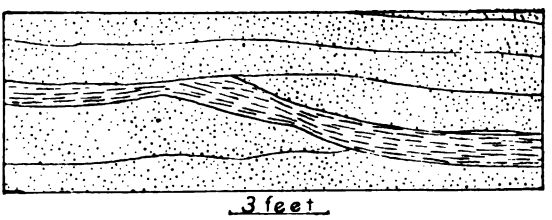

FIG. 1. Bedding in Orienta sandstone, Siskowit Pt., Bayfield County.

most striking and interesting feature of the bedding is what may be called "down curves." These are usually seen only in cross section so that their character in three dimensions can not be observed. They may be sections of curved cross bedding, or actual troughs. In width they range up to 200 feet, but most are of far less size. Two of the clearest seen are shown in Plate IV, p. 30, and Fig. 2. The first shown is not over twenty-five feet across and is filled with curved beds. Sometimes the filling is a bed of red shale, or beds of horizontal sandstone, usually thin-

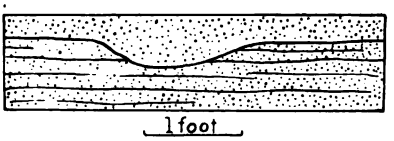

FIG. 2. Channel in sandstone layers Quarry northeast of Washburn, Bayfield County.

ner-bedded than the rock below. Oftentimes the relation of the down curve to the underlying rock is not clear; but in the instance shown in Plate IV, B, the underlying rock is cross bedded; here it is seen that the depression cuts through the previously deposited layers. In other instances the down curve appears to be an actual bend in the bedding.

The origin of these interesting features is thought to be in part curved cross bedding (cf. p. 30) and in part erosion by

streams or currents of beds previously deposited. In this case the hypothesis of subaerial origin of the formation is favored. The great diversity of forms, often incomplete in development, leads one to think that different agencies caused the various forms.

A less common feature is an upward bending of the strata as shown in Plate I, B, frontispiece, and Fig. 3. Sometimes even sharper forms occur, but most are comparatively gentle domes or ridges.

Cross bedding is very common, scarcely an exposure being free from it. Every gradation from the normal type to the pecu-

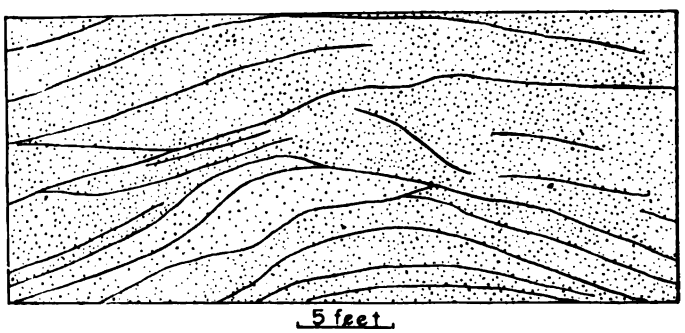

FIG 3. Bedding in Orienta sandstone, Amnicon River, Douglas County.

liar features described above can be found. Usually the inclined layers do not extend through more than a few feet of stratigraphic thickness, but some long gently inclined partings may represent cross bedding developed on a huge scale. At some places, where the waves have washed off a large terrace along the shore, cross bedding may be seen in three dimensions. Then the inclined layers are often found to be curved into sags, domes, and other irregular forms; as suggested, many down curved layers may be simply cross sections of this kind of cross bedding.

The dip of the inclined beds is often rather steep, but no cross bedding of the type usually ascribed to wind action was observed. The direction of dip was observed with some care. It is almost always toward a northerly or easterly direction. In the Devils Island sandstones alone are southerly or southwesterly dips at all common, although they are found occasionally in all the lower strata. The significance of this fact is the presumption

A. Down-curve in upper beds of Orienta sandstone, west side of Sand Island, Bayfield County.

B. Horizontal sandstone beds, filling channel in cross-bedded layers, Orienta sandstone, west of Herbster, Bayfield County.

that the material for this formation was brought mainly from the northeast, while that of most of the group came from the opposite direction.

Iron Banding. In noting the colors of the Bayfield group the observer is often confused by the tendency of the red beds to weather white, while many white beds are discolored to a brown shade on the surface or are stained red by iron from overlaying rocks or drift. Much more light colored sandstone exists than is generally supposed. The rapid variations of color are often very striking. When the change takes place along a joint it gives the appearance of a fault which is often very deceptive. In general it may be said, that the coarse grained and often the thick bedded layers are lightest in tint, while the thin bedded and shaley beds are both darkest and most varied in color, although most affected by spots and streaks of lighter tint. Mottling and irregular blotching of red and white, however, is not confined to these beds. When this kind of rock is seen below water, where the surfaces are cleaner and the colors brighter than where exposed to the air, the effect is very striking. Sometimes red circles are seen in white sandstone, inclosing spots of white. Often very irregular markings occur. Fine banding along the bedding is by far the most common, but one seldom has to follow the bands far before they leave the planes of deposition to form irregular curves. True concretions of iron oxide are, however, not very common.

The origin of these varied features is evidently the work of ground water, but the reason for the curious forms is not known. It appears probable that most of the iron was originally deposited in the thin-bedded, fine grained layers and in the massive brownstones, and that it has spread from them into the rest of the rock. The light color of the coarse grained sediments suggests either the action of leaching of these more porous beds, or that the iron was never deposited in them. A striking instance of secondary coloration was observed in a cross bedded layer near Pikes Quarry, Bayfield County, in which the upper half was red and the lower nearly white, the line of junction thus cutting the bedding. Although the iron oxide is not an important cement in the firm brownstone, it may be the dominant cement in some of the less indurated sandstones, no thin

sections of which have been examined. The writer is inclined to believe that such curious forms as are shown in Plate I, B, frontispiece, are due to partings along the lines of iron banding. Generally these apparent folds or sharp basins occur along joints, thus strengthening the suggestion of an origin due to irregular cementation, although, however, all are not to be explained in this manner.

Pebbles and Clay Pockets. In a formation entirely devoid of fossils, like the Bayfield group of sandstones, the derivation of the pebbles in the conglomerates is a subject of considerable importance. No thick beds of conglomerate occur within the group, but pebbles are found very commonly on both normal and cross bedding planes and to a less extent scattered through the sandstone or even through the shale. The Devils Island sandstone, however, is free from them. In size these pebbles average about an inch in diameter, the largest being some four inches across. All are well rounded. By far the greater portion of the pebbles are porphyries and amygdaloids with some basic traps; these were obviously derived from the Middle Keweenawan. Next follow in order of their abundance, vein quartz, red and white quartzite, iron formation, chert, slate, and granite, all derived from the Huronian and older rocks.[1] It should be noted that all the pebbles with the exception of the traps are of very resistant rocks, while even those are the hardest parts of the formations from which they were once worn. No debris from the recognized Keweenawan sediments (Oronto group, etc.) could be discovered.

Often associated with the pebble deposits are small cavities which when seen in fresh sandstone are found to contain red or green clay. Many of these show remnants of decomposed trap pebbles making their origin at once evident. Others are larger and of irregular shape. Yet others are small and flattened, appearing at first sight much like the casts of shells. But again, in fresh rock they are always found to be filled with clay. A common feature of clay pockets occuring in red rock is a surrounding rim of white.

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[1] Owing to weathering, the identification of many of the small trap pebbles is quite difficult.

The origin of the irregular or flattened clay pockets must be nodules of clay laid down with the rock[1]. Such clay lumps are often found in recent deposits. They are formed of flakes of somewhat indurated clay which will not mix with sand, or washed cut by streams, or dried and broken up by sun and wind in connection with mud cracks. Mud cracks are not often found in the Bayfield group of sandstones, owing to the scarcity of clay and the ease with which they are overlooked in natural exposures.

Chequamegon Sandstone

General Character and Extent. The youngest formation of the group is the Chequamegon sandstone, so named from the exposures in the now almost idle quarries on Houghton Point on Chequamegon Bay, Bayfield County. In areal distribution, this formation underlies all the Apostle Islands southeast of a line drawn from Sand Point to Devils Island. How far it extends beneath the thick drift of the Bayfield Ridge is a matter of conjecture. The Chequamegon formation consists mainly of brown quartzose sandstone.

Thickness. As the initial dip of the formation could hardly have been over one degree, or about 100 feet per mile, and that presumably towards the northeast (cf. p. 102) we may compute a thickness of nearly two thousand feet; but in order to allow for the probable lessening in dip towards the southeast, as well as a tendency to overestimate the degree of inclination, a thickness of 1000 feet is regarded as nearer the truth.

General Section. The Chequamegon sandstone may be divided into several more or less distinct members as follows:

Washburn beds. Soft red and white sandstones with much banding and mottling of the colors; beds usually thin with few pebbles or shale layers, which sometimes show mud cracks.

Quarry or Brownstone beds. Heavily-bedded dark brown ferruginous sandstone with pebbles and clay pockets; between heavy beds are thin-bedded layers and lenses of red, micaceous shale.

[1] The writer did not observe any evidences of decomposing trap boulders. Cf. Irving, R. D., Geol. of Wis., 1873-9, vol. III, p. 209.

Main beds. Much the same as the brownstone but with more irregular bedding, cross bedding, light colored and coarse pebbly sandstone, and red shale beds. (It may be that the quarry rock is only a phase of this division.)

Basal beds. Thick, cross-bedded layers of white or brownish sandstone with pebbles; lenses of red and yellow thin-bedded rock; some ripple marks.

LOCAL DETAILS.

The youngest or Washburn beds of the Chequamegon sandstone are seen in the shore cliffs south of Washburn on Chequamegon Bay. Here are exposures up to nearly 40 feet in height of soft sandstone of all colors. There are many rapid variations from white to the darkest red, while mottling is very common. No pebbles were observed. The beds range from several feet in thickness down to a fraction of an inch in the dark red sandy shale beds.

At the Barksdale works of the E. I. Du Pont Denemours Powder Co. a well shows the greatest thickness of the Chequamegon sandstone known at one locality. It is clear that the Devils Island sandstone was not reached.

LOG OF WELL AT BARKSDALE POWDER WORKS

Drilled in 1906. Situated in sec. 23, T. 48, R. 5 W. at elevation of about 750 ft. A. T. Samples sent by courtesy of U. S. Geological Survey.

Sample No.		Thickness	Depth
Pleistocene:		Feet	Feet
1	Grayish-red, sandy, non-calcareous clay.....	70	
2	Very calcareous reddish-gray "hard-pan" or sandy cemented till	20	90
Chequamegon sandstone:			
3	Soft medium grained light reddish quartz sandstone	18	
4	The same, slightly darker and harder.....	27	
5	Pinkish white coarser and subangular grained quartz sandstone	25	
6	Soft, finer grained reddish quartz sandstone	20	
7	Soft, very coarse gritty or conglomeritic red sandstone mixed with some finer sandstone	20	

8	Soft, nearly pure quartz sandstone, grains subangular and of medium size.....	30	
9	Sample missing. Said to be same as last...	15	
10	Soft fine to medium grained pinkish quartz sandstone	15	
11	Much the same as the last but with somewhat more rounded grains	20	
12	Nearly pure white sandstone, otherwise same as last	20	
13	Sample missing. Said to be soft red sandstone	45	
14	Sample missing. Said to be white conglomerate with much water.....	30	375
	Depth of well	375	375

At the quarry just north of the city very similar rock is seen. (see Fig. 2, p. 29). Between the thicker beds occur thin-bedded and shaley partings which sometimes show mud cracks. These exposures show a dip of about one degree to the south.

Only comparatively small exposures occur on Madeline Island, the best being on the northernmost point. These beds show a darker color, together with red shaley beds, and pebbly layers. They appear to be a portion of the quarry beds.

The now virtually idle quarries on Houghton Point north of Washburn are in heavily-bedded brownstone.[1] Between the heavy layers is frequently found a foot or more of thin-bedded or softer sandstone, while lenses of red micaceous shale often occur. At other places the bedding planes are marked by coarse yellowish grits or layers of pebbles. Clay pockets also occur. Plate III, A, p. 26, shows a thin section from this locality.

Pike's quarry south of Salmo shows the greatest vertical extent of the formation so far as known in any single exposure. The following section, from top down, shows the downward gradation of the quarry beds (numbers 7 to 9) to the less regularly bedded and variable colored layers of the main beds:

[1] Buckley, E. R., Building and Ornamental Stones of Wisconsin, Wis. Geol. & Nat. Hist. Surv., Bull. IV, 1898, pp. 187-192.

SECTION AT PIKE'S QUARRY, SEC. 33, T. 50, R. 4 W.

	Thickness
9 Weathered and broken brownstone	23 feet
8 Thin bedded and cross bedded red shaley sandstone with yellow streaks	6
7 Heavily bedded brownstone with very few clay pockets, the best quarry rock	33
6 *Unexposed* below level of railway track	15
5 Heavily bedded brownstone in lake cliff, the top much broken up	35
4 Thin bedded, red, shaley sandstone	8
3 Heavy layer of brownstone	8
2 Gray to deep red, yellow, and white sandstone, varies from shaley to pebbly with much cross bedding, the coarser phases having the lighter colors	12
1 Heavily bedded coarse pebbly brown sandstone	20
Total thickness, about	150 feet

Immediately south of the docks at Bayfield is a good exposure of brown sandstone in the cliffs. The usual thin bedded and sandy shale partings occur between the beds, and in one place is found a small lense of pure clay shale, a foot or two in thickness. This is of varying shades from deep red to gray and green, and grades into the usual sandy shale; the associated yellow sandstone layers are also seen.

On the south end of Basswood Island is an abandoned quarry which shows about 25 feet of brownstone in heavy layers.[1] The bedding planes are curved both up and down from the normal. A shale layer is found between the brownstone beds in the quarry and the same material is said to have been reached by boring not far below the bottom of the quarry. Pebbles and clay pockets are abundant. Plate III, B, p. 26, shows a thin section of this rock.

A small quarry was once operated on the northeast corner of Hermit or Wilson Island.[2] The neighboring shore cliff shows thin bedded and cross bedded yellow and white mottled layers be-

[1] Ibid., pp. 178–182.

[2] Ibid., p. 185.

tween the heavy beds of brownstone. A thin section shows fairly well rounded grains averaging nearly 0.4 mm in diameter. About a fourth is altered feldspar including much microcline, although orthoclase is predominant.

Stockton Island shows extensive outcrops on its eastern end. There the waves from the open lake have worn some striking caves and deep coves along the joints. The sandstone is somewhat redder in color than the quarry beds. A few shaley layers are seen but most of the bedding is heavy. Some long partings dipping gently to the south resemble, huge cross bedding, but are probably inclined joints. Cross bedding is common. At the southeastern end of the exposures occurs hard, cross bedded, white sandstone. Similar rock is also seen on Presque Isle Point.

Near the southwest corner of Stockton Island is a large abandoned quarry which shows a thickness of 73 feet of brownstone in the main opening.[1] Above this another excavation discloses rock which is mottled with white. The upper layers all show clay pockets. The partings are often shaley and show cross bedding. They pinch out rapidly, never having any great horizontal extent. Sometimes they end on downward pitches of the bedding, but in other places the layers bend up and are cut off by the heavy layer above as cross bedded layers are.

Outer Island exhibits a fine exposure along almost the entire length of its eastern side. The sandstone is much varied in color, ranging from the usual brownstone to pure white. The changes are very rapid and often take place along joints. In general the coarse grained cross bedded layers are lightest in tint. Plate I, B, frontispiece, represents a curve in the bedding seen near the southern end of the island; others occur but are not so distinct.

Some interesting exposures occur on the east side of Oak Island. At the northeastern corner, heavy beds of brownstone with interbedded dark shaley layers are seen. Coarse yellow grits also occur. Toward the south, lenses of thin bedded yellow and white banded sandstone appear, and also some hard white and brown coarse pebbly layers.

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[2] Ibid., p. 183.

On Point Detour and the adjacent headlands[1] occur beds of brown sandstone with the usual shaley partings. The depth to which weathering here extends is unusual, being often 20 feet or more.

North Twin Island shows strata near the bottom of the Chequamegon formation. White to brownish heavy cross bedded layers with occasional large ripple marks occur.

Bear Island shows on its eastern coast a very good section. The southeasterly dip is here more pronounced than it is to the southeast, so that some 400 feet of the stratigraphic thickness is apparently seen. However, the layers pinch out and vary so rapidly that an exact determination is impossible. As we go north we descend to successively older and older strata. At the south, brown sandstone with irregular cross bedding and lenses of thin bedded yellow and pink sandstone occur. But towards the north end the color becomes gradually lighter until hard cross bedded white beds take their place. These basal beds show a few ripple marks. At some points wide terraces of rock have been washed clean by the storms so that an excellent opportunity is given to study the curious forms of the curved cross bedded layers (see p. 30).

On York Island, at the northwestern cape, is a fine exposure of the basal layers in a clean wave-swept terrace. White and reddish sandstone, with grit and conglomerate, occur as well as small lenses of thin bedded red and pink layers.

At the south end of Devils Island, which is entirely surrounded by a rock cliff, the light colored basal layers of the Chequamegon sandstone are seen. There are interbedded layers similar to the main body of underlying Devils Island sandstone, so that no very sharp line of demarkation can be drawn.

Devils Island Sandstone.

General Character and Extent. The formation of the Bayfield group, which conformably underlies the Chequamegon sandstone, is called the Devils Island standstone, from the excellent exposures on the island of that name. It is distinguished

[1] Owen, D. D., Chippewa Land District, p. 54; Geol. Survey of Wis., etc., pp. 268, 305.

from the other formations of this group by its thin bedding, well rounded, medium sized quartz grains, which are almost free from any coating of iron oxide, by ripple marks, and by its pink and white color. Banding and mottling of the colors is frequent. A few iron concretions occur. No shale beds, feldspar grains, clay pockets or pebbles are known in this formation. The formation is much more porous and friable than the others of the group. For that reason more striking and larger sea caves have been worn in the Devils Island sandstone than in any other horizon.

The Devils Island sandstone outcrops along a narrow belt stretching for twenty-five miles southwest from the island from which it takes its name. Fine exposures occur in the cliffs of Sand Island and Squaw Bay (Plates V, B, XXIII, A, p. 94).[1] Lesser ones are seen on Siskowit River and Lost Creek near Cornucopia. Twenty-five miles to the southwest an isolated exposure on Brule River corresponds so closely in character, that there is little doubt that it is to be placed in this formation. According to the writer's interpretation of the structure of the district, this formation must lie immediately beneath the drift south of Washburn, but no exposures of it are there known. It may pinch out or otherwise disappear in the interval.

Thickness. The thickness of the Devils Island sandstone cannot be directly measured, but a computation based upon the width of outcrop and average dip places the figure at about 300 feet.

Ripple Marks. The only portion of the Bayfield group which shows ripplemarks in any abundance, is the Devils Island sandstone and some of the beds immediately above and below. The accompanying diagrams show the most common types. Most have symmetrical ridges, little if any sharper than the intervening troughs. The other type has one side of the ridge much steeper than the other, as shown in Fig. 4, c, and Fig. 5, p. 40. Few were observed which show the subordinate ridge in the hollow, such as is often seen in modern ripple marks formed on the lake bottom (Fig. 4, b). This is, however, a

[1] Owen, D. D., Chippewa Land District, p. 55; Geol. Survey of Wis., etc., p. 268.

feature which is readily overlooked. The ripple marks occur both on cross and normal bedding planes, and where marked by a cement of iron along the bedding the effect upon the outcrop is very striking (Fig. 5). In size they average one to two inches from crest to crest, but occasionally much larger ones are seen.

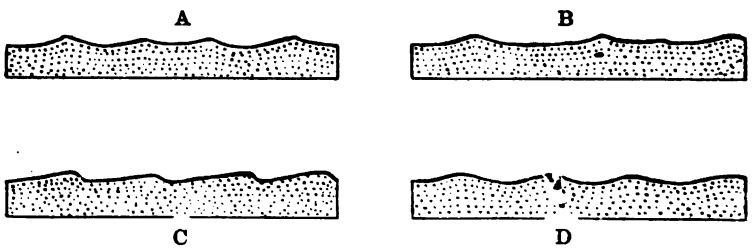

FIG. 4. Types of ripple marks.

It is believed that the symmetrical ripplemarks are the result of wave action in standing water; and that the unsymmetrical form (Fig. 4, c) was formed by currents, either of water or air.

Cross Bedding. The common cross bedding of the Devils Island formation is more regular than much of that in the other members of the Bayfield group. The curious irregular curved forms there noted are seldom seen. The direction of

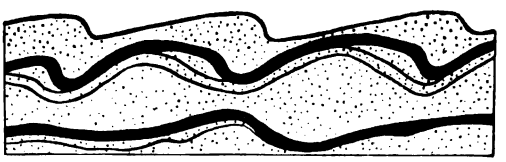

FIG. 5. Ripple marks marked by iron banding in Devils Island sandstone (Specimen 11,058). One-half size.

dip of the layers is usually to the south or southwest but there are some exceptions, although on the whole it is conspicuous for being in a direction opposite to that prevailing in the other formations. This fact is thought to mean that the material of the Devils Island sandstone was brought from a different direction.

A. Sea caves in upper beds of Orienta sandstone, west side of Sand Island.

B. Sea caves in Devils Island sandstone, near Squaw Bay, Bayfield County.

Orienta Sandstone

General Character and Extent. Underlying the Devils Island sandstone occurs the lowest formation of the Bayfield group, the Orienta sandstone, so called from its exposure in the quarries near the village of that name. In its upper portion this formation resembles the Chequamegon sandstone very closely, so that the possibility of repetition of that formation by faulting was considered. It is seen, however, that in the vicinity of Cornucopia the uppermost beds of the Orienta pass beneath the Devils Island sandstone, although the actual contact is not exposed so far as known. Moreover, there is no repetition, so far as could be discovered, of the Devils Island formation to the west. In its lower portion, and indeed to some extent throughout, the Orienta contains more feldspar, mica and magnetite grains than the younger formations, the relative amount increasing towards the bottom, as do beds of red shale.

The Orienta sandstone underlies the Western Plain, extending from the line of outcrop of the Devils Island formation, all along the south coast north of the Douglas Range and into Minnesota. Folding brings it up near Ashland, where rock believed to be a part of it outcrops on the South Fork of Fish Creek, and it is found beneath the thick drift in deep wells.

Thickness. As with the Chequamegon, there is no direct means of measuring the thickness of the Orienta sandstone. A computation based on a uniform dip of but one degree places the thickness on Brule River at about 1000 feet. This section is not good enough to be correlated with that shown on Middle River, where the formation is turned up by the thrust fault of the Douglas Range, exposing some 2,700 feet. As the Devils Island formation does not occur there, it appears certain that the Middle River section is all Orienta sandstone, thus placing the total thickness of the formation at 3,000 to 3,500 feet; 2,495 feet of this formation is penetrated by the deep well at Ashland (see p. 65), and 1,110 feet is exposed on Fish Creek.

General Section. The following section shows the subdivisions of the Orienta sandstone from the top down. In the future it is possible that some parts may be distinguished as separate formations:

	Approximate Thickness
Upper beds. Mainly white and red sandstone with a few ripple marks	300–400 feet
Upper brownstone (of Port Wing)	500–700
Copper Creek beds. White and pink fine grained sandstone with magnetite and mica grains and a few ripple marks	75–100
Main beds. Brown, red, and white sandstones, becoming progressively more felspathic towards the bottom, with thin beds of red shale	1800–2000
Total thickness, about	2700–3200 feet

LOCAL DETAILS

Aside from the small exposure believed to belong to this formation, on Fish Creek near Ashland Junction, which will be described in Chapter V, the easternmost exposure of the Orienta Sandstone is on Sand Island. Here and on Eagle Island[1] and Squaw Point (Plate V, A, p. 40) to the west, occurs white cross-bedded, ripple-marked sandstone much resembling the basal beds of the Chequamegon formation. A few layers of red sandstone occur and there is much banding of the colors. A considerable amount of decomposed feldspar is seen among the sand grains.

To the west, on Siskowit Point, the downward gradation of this type to the brownstone beds may be seen. Lenses of red shale also appear (Fig. 1, p. 29). A small quarry formerly operated here produced red and white sandstone. Similar sandstone with red, shaley, and yellow gritty layers occurs on Bark Point, across a bay by that name to the west.

Just west of the little settlement at Herbster is a bold rocky point projecting out from the sandy coast cliffs.[2] Here the sandstone is pebbly and cross bedded. Plate IV, B, p. 30, shows an interesting trough in the bedding seen here. A quarry was once started at this locality.

The quarries at Port Wing are still operated at times and produce some of the best brownstone in the region. This rock is heavily bedded, free from clay pockets, has few pebbles, and

[1] Irving, R. D., Geol. of Wis., 1873–9, vol. III, p. 208.

[2] Owen, D. D., Geol. Surv. of Wis., etc., 1852, p. 269.

is of a somewhat redder and more cheerful tint than the brownstone of the Chequamegon sandstone. In the quarry some pebbles were observed along the bedding planes, together with black magnetitic layers, and a little white sandstone.[1] Plate VI, A, p. 44, shows a thin section of this rock. About a fourth is feldspar, mainly orthoclase, but including some microcline and plagioclase. The locality is notable for the unusual fact that the rock is sound clear up to the top and shows glacial striae.

Another good quarry was formerly operated on the east bank of Iron River near Orienta, in the western part of Bayfield County.[2] The southeasterly dip of the formation, combined with the fall of the river, brings one to successively higher and higher strata in ascending the stream. We pass from the heavily bedded brownstone up to thin bedded white and red banded rock. Near the road crossing, occur white and yellow heavier beds with thin layers of green shale.[3]

West of the mouth of Iron River no exposures occur on the coast. Only two small outcrops occur on Brule River below those of the Devils Island sandstone. On Poplar River are good outcrops for several miles above the mouth, but as the dip here is generally less, no great thickness can be observed. The rock is thought to be part of the upper brownstone. Much is thin bedded and grades to coarse yellow sandstone. The magnificent section seen on Middle River shows the lower portion of the formation and will be described in detail in Chapter V.

West of Middle River, exposures are much less satisfactory. The Copper Creek and main beds are the only ones found. On Amnicon River for about three-fourths of a mile below the falls, at the contact with the trap, occur good sandstone exposures. The dip is southeasterly, except close to the trap, and some 275 feet of beds is thus exposed. Of these the lower 200 feet is mainly heavily-bedded brownstone, which once was quarried to

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[1] Buckley, E. R., op. cited, pp. 201–205.

[2] Ibid., p. 209.

[3] Owing to bad weather the survey of Iron River was not completed. No exposures were seen or reported where we would expect to find the Devils Island sandstone (see map). Sweet, E. T., Geol. of Wis., vol. III, 1873-9, p. 322.

a considerable depth.[1] Associated white and yellow pebbly phases and magnetitic bands occur. These features serve to distinguish the beds from the upper brownstone of the Port Wing quarries, although the possibility of lateral change in the formation must be taken into account. Above these layers occurs a gradual transition to the Copper Creek beds. These are mainly thin bedded pink or red and white fine grained sandstone. Much cross bedding, sometimes curiously curved, occurs (Fig. 3, p. 30). No ripple marks were observed, and this fact, taken in connection with fine grain, magnetite grains, and small thickness lead the writer to regard this as a part of the Orienta sandstone rather than a lateral change in the Devils Island formation. It is also simpler on structural grounds to assume this correlation, for it is entirely possible that these beds occur under one of the unexposed intervals in the Middle River section to the east.

Similar beds appear to occur at two small exposures which were not visited by the writer. One of these is in Sec. 30, T. 48, R. 10 W. and was not discovered by any of Prof. Grant's party.[2] Another outcrop in Sec. 7, T. 47, R. 13 W., was examined by one of Prof. Grant's assistants and a sample preserved, which shows the rock to be very like that at the falls of the Amnicon River. It is a pebbly reddish and white sandstone.

On Copper Creek next to the contact with the traps, a small thickness of thin-bedded, ripple-marked, red and white spotted sandstone is exposed, which in many respects resembles the Devils Island sandstone. It is, however, much darker in color and is therefore thought to belong to the same horizon as the rocks described above.

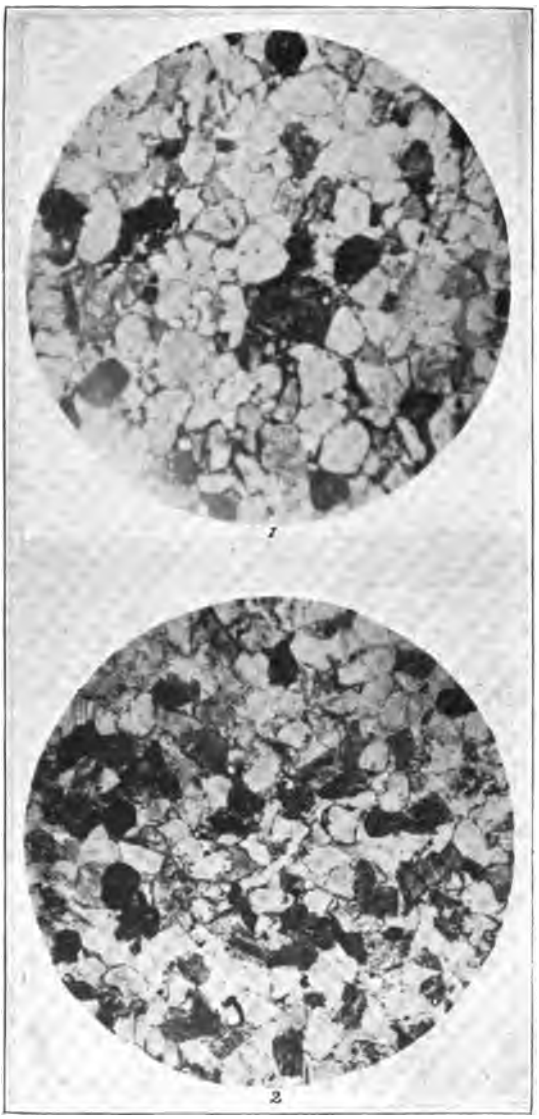
Farther to the west, below the lower falls of Black River (Plate XIX, p. 80) occurs red and white spotted irregularly colored sandstone varying much in bedding and coarseness of grain. The dip may be sufficient to expose as much as 200 feet of strata, showing a somewhat similar secession as at Amnicon River (see p. 43). No true brownstone was observed and there is a comparative abundance of magnetite, micas, and ferromagnesian

[1] Buckley, E. R., op. cited, p. 208.

[2] Sweet, E. T., Geol. of Wis., 1873–9, vol. III, p. 348.

PHOTOMICROGRAPHS IN ORDINARY LIGHT, MAGNIFIED 12 DIAMETERS. (Buckley, Bull. IV, Plate LXIV).

A



B

A. Orienta sandstone (specimen 4717) from Port Wing. The section shows more feldspar (mainly orthoclase, but including some microcline and plagioclase), iron oxide, and ferromagnesian minerals, than those from the Chequamegon sandstone, although not notably different from Plate III, B, p. 26. The cement in this specimen is partly iron.

B. Orienta sandstone (specimen 4718) from quarry on St. Louis River, in bed 1 of section on p. 70. Nearly one-fourth of the rock is feldspar, mainly orthoclase, but including as usual some microcline and plagioclase. The cement is in part argillaceous, being composed of the alteration products of the feldspars.

minerals. Ripple marks occur but rarely and cross bedding is not very abundant, but many clay pockets and pebbles were observed. Some of the thicker beds are of yellowish to white quartz sandstone. One such was observed to fill a hollow in the thin bedded red layers. The latter type of rock appears to be more abundant in the upper part of the section but often occurs as lenses in the heavier bedded sandstones.

In Sec. 29, T. 47, R. 14 W., occur several small exposures of yellow and white fine grained hard sandstone, very much like some of the beds exposed on Copper Creek. A well at Foxboro in Sec. 6, T. 46, R. 15 W., almost on the west line of the state, shows the same kind of rock,[1] as do some small exposures near Holyoke visited by Professor Grout.[2]

A small exposure of sandstone is said to exist on the Nemadji River in the NE¼ Sec. 27, T. 48, R. 14 W., but was not visited by the writer.[3]

The exposures of the Orienta sandstone on St. Louis River are described on p. 69.

Economic Products. The only product of economic value derived from the Bayfield group is building stone.[4] This is obtained from the most ferruginous phase of the sandstone which is commonly known as "brownstone." Apparently this rock is found only in certain more or less well defined horizons. It will be noted that the quarries, especially those in the Apostle Islands, are arranged in a nearly straight line along the strike of the formation. Therefore but one horizon of good quarry rock is believed to exist in the Chequamegon formation, although good stone was seen at many scattered points. Less is known about the Orienta sandstone. The best brownstone is that found at Port Wing and Orienta, but it is most probable that the brownstone quarry on Amnicon River is at a lower horizon.

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[1] Drillings sent by C. N. Edin, Dedham, Wis.

[2] Personal communication.

[3] Sweet, E. T., Geol. of Wis., 1873–9, vol. III, p. 318.

[4] A full description of the quarries, including a list of buildings constructed with Lake Superior stone, is found in Bull. IV, Wis. Geol. and Nat. Hist. Survey, Building and Ornamental Stones of Wisconsin, by E. R. Buckley, 1898, pp. 167–219.

The quarry at Fond du Lac does not produce a true brownstone, the rock being firmer, more felspathic, and irregularly colored red and white.

Condition of the Quarry business in 1910. When the writer visited the district, no quarry happened to be in operation. The Port Wing quarries, which alone are operated on an extensive scale, closed down about the first of July. A very little stone had recently been quarried at Houghton. The Fond du Lac quarry is operated whenever the height of water in the river permits shipments, but is not equipped to furnish anything but rubble and irregular blocks.

Causes of Decline. The causes of the almost complete abandonment of this once apparently flourishing industry do not lie wholly in the character of the stone itself.[1] A few decades ago brownstone was a very popular building material in the eastern part of this country, so that when a similar stone was discovered in Wisconsin it was at once exploited. Between 1868, when the first quarry was opened on Basswood Island,[2] and 1893 the business continued to grow. A few years before 1893, a boom took place at the head of the lakes. As in all other business enterprises, speculators then rushed into the brownstone industry. Stone, often of inferior quality, was put out at ruinously low prices. The bad results from the use of this low grade material naturally reflected upon the reputation of the good. Then came the inevitable panic, resulting from the unnatural expansion of business. The demand for stone decreased greatly and never again reached its former extent.

In the meantime, the brownstone buildings of the east had begun to look shabby and a cheerful light stone was demanded. This was supplied by the Bedford limestone, which is nearer the best markets and possesses the great advantage of softness. Tools dull much more rapidly in cutting sandstone, a fact witnessed by the extensive blacksmith shops of the Lake Superior quarries. Before the Lake Superior companies could recover from the results of their folly before the panic, this light stone had captured the market. By 1897 very little stone was being

[1] Buckley, E. R., op. cited, p. 211.

[2] Irving, R. D., Geol. of Wis., 1873–9, vol. III, p. 209.

taken out and today only two quarries are producing first class building stone. Plants representing an investment between two and three million dollars are now idle; some have been burned; in most the machinery is rusted and useless and the buildings are falling to pieces. At several quarries large piles of cut blocks ready to ship remain unsold.[1] Perhaps now that business at the head of the lakes is developing upon a more sane and wholesome basis than formerly, quarrying will be resumed; for the stone has a useful field for buildings in smoky cities, as it does not show dirt like the lighter toned materials now in fashion.

[1] In 1912 some of these were being shipped.

CHAPTER IV

THE ORONTO GROUP AND OLDER FORMATIONS, AND THE EXTENSION OF THE SANDSTONE GROUPS IN MINNESOTA

Nomenclature. Beneath the Bayfield sandstone group described in the last chapter, is a great thickness of arkose sandstone and shales, nearly all red in color, and for the most part occupying a highly tilted position wherever exposed. On account of these differences, these rocks were separated by the former Geological Survey of Wisconsin from the overlying horizontal quartzose sandstone (see p. 16). At its base this arkose group is interbedded with the traps, thus showing that it is a part of the Keweenawan series; but the bottom of this upper division of the series is assumed to be the base of a thick conglomerate called the Outer Conglomerate, above which horizon no igneous rocks occur.

With the exception of the basal portion, this group has not heretofore been divided into formations. Professors Lane and Seaman have recently applied the name Freda to the sandstone immediately overlying the black shale beds (Nonesuch formation) just above the Outer Conglomerate.[1] As this formation (sometimes known as the Western sandstone of Michigan) is only a small portion of the entire thickness of sediments below the Bayfield group which have not yet been studied in

[1] Lane, A. C., and Seaman, A. E., Geological Section of Michigan, Rept. of State Board of Geol. Survey, 1908, p. 23; Jour. of Geology, vol. 15, 1907, p. 36.

detail, it seems best to give a new name to the entire group and retain the name Freda for this formation. It will therefore be termed the Oronto Group, from the excellent exposures near the bay of that name in the northern portion of Iron County. The limits of the group may be fixed at the bottom of the Outer Conglomerate as a base, and the top of the highest thick beds of red shales and well-marked arkose sandstones as the top.

General Character. The Oronto Group is composed of conglomerate, sandstone, and shale; the last probably predominating, although not often exposed. In color it is usually some shade of red, but a characteristic feature is banding, streaking, and spotting with greenish white. The white beds are seldom more than a few inches thick. Often the light color also extends along the joints. In the material of the component grains it differs mainly from the Bayfield group in having a greater proportion of undecomposed minerals, feldspars, micas, and ferromagnesian compounds, as well as more magnetite and calcium carbonate. Quartz grains are, however, present in considerable quantity; but are never, so far as known, predominant throughout any considerable thickness of strata. The shale is usually sandy and micaceous, but there are considerable beds of fine clay shale. Nearly always the shale beds are more brightly colored than the coarser grained strata.

Areal Extent. In areal extent the Oronto Group underlies all of the Eastern Plain (see p. 12), between Ashland and the Southern Trap Highland, but it is exposed at but few points. It is probable that only the harder beds are exposed, since these would form the ridges now buried beneath the drift, which is usually so thick that only a few very deep wells enter the rock. It here forms a series of open folds (see p. 92). Isolated areas of rocks believed to belong to the Oronto Group occur also on Middle and St. Louis rivers in Douglas County, and rock of the same type is penetrated by deep wells in Superior. The Oronto Group is believed to extend far into Minnesota, for rocks of the same type have been found by drilling to lie beneath the Paleozoic sediments.

Thickness. The thickness of the Oronto Group can only be determined by computations based upon discontinuous exposures. The sum of the stratigraphic thicknesses actually exposed is

nearly 10,000 feet, but evidently the total must be much greater. On Montreal River it is possible that a thrust fault, dipping to the north, might cause a repetition; but no direct evidence indicating its existence was discovered.[1] Computation places the thickness of the Freda sandstone between the top of the Nonesuch shales and Lake Superior at 12,600 feet. Should an initial dip of even 10 degrees be subtracted, (which is much too great), the result would be 11,700 feet. On Fish Creek to the west, where there is every probability that the strata are thinner, since they thin rapidly in that direction at all lower horizons,[2] a thickness of fully 8,000 feet is indicated. There the jointing and shearing (see p. 93) do not indicate that the thickness is expanded by faulting. Since the rocks of this locality are believed to lie at a horizon above those of Montreal river, a total thickness of the Oronto Group of some 21,000 feet is indicated. This figure agrees with other computations based upon the dip, and appears to be conservative—provided lateral variations in the character of the strata along the strike, and concealed faulting have not confused the true sequence to a greater extent than now seems probable.

Subdivisions. The Oronto Group may tentatively be subdivided into the following formations; the basis of the division is in part structural but is mainly lithologic, and therefore rather unsatisfactory, owing to the possibility of lateral variation as mentioned above:

	Thickness
Amnicon Formation. Red and greenish shales, arkose sandstone, and some conglomerate (1050 feet exposed)	5,000 feet
Eileen Sandstone. Red and white somewhat quartzose sandstone (1800 feet exposed)	2,000
Freda Sandstone. Fine-grained red and greenish arkose sandstone with a little conglomerate at top and bottom (about 8000 feet exposed)	12,000

[1] Lane, A. C., and Seaman, A. E., Geol. Section of Mich., Report of State Board of Geol. Survey of Mich., 1908, pp. 33, 38.

Personal communications.

[2] Irving, R. D., Geol. of Wis., 1873-9, vol. III, p. 12.

—— Copper Bearing Rocks, Mon. U. S. G. S., vol. V, pp. 153-230.

Amnicon Formation—Middle River, near east end of exposure (see Plate XIII). The rock is hard, green, and red, very fine-grained sandstone, in beds varying in thickness from a foot to a fraction of an inch. The green phase is calcareous (see page 52, and Plate XVI A, p. 72). The bedding planes show abundant ripple marks of the symmetrical type, as well as mud cracks. These beds dip south at high angles and are shown by ripple marks to be overturned. (Grant, Bull. VI, Plate VI.)

Nonesuch Formation. Black, gray and red arkose and shale (maximum)	350
Outer Conglomerate, coarse conglomerate (maximum)	1,200
Total maximum thickness, about	21,550 feet

Composition. The rocks of the Oronto Group are mainly composed of angular to subangular fragments, derived from igneous rocks without much chemical decomposition. The only marked exceptions are some of the red clay shales. At the base in the Nonesuch formation, occur many layers of black sandstone composed of nearly unaltered fragments of trap, so thoroughly cemented with calcite that they are readily mistaken for igneous rocks. Higher in the group there appears a greater proportion of debris from quartzose rocks. In the conglomerates there is little difference in the source of the pebbles from those found in the Bayfield group. They comprise traps of many varieties (porphyries probably predominating), quartzite, iron formation, chert, vein quartz, slate, and granite. In the coarse arkose grits, fragments of igneous rocks of both basic and acid varieties are plainly seen, but these rocks were not studied in detail. In most of the group the grain is so fine that the microscope is needed to determine the material; and as no detailed study was made, information is available for only a few varieties of rock. This will be found under the head of local details, page 54. The component grains are mainly feldspars (both orthoclase and more basic varieties, the latter being often too much altered to determine), quartz, mica, magnetite, ferromagnesian minerals and fragments of fine-grained igneous rocks. On the whole, the grains are less rounded than those of the Bayfield group and although extremely variable, appear to average considerably smaller in size. Often a somewhat clayey reddish or greenish matrix is seen, perhaps derived from these fine-grained porphyries, from the decomposition of feldspar, or sometimes mainly composed of iron oxide. The cement is often calcium carbonate, but enlargements of the feldspar and quartz grains are probably the dominant cement. Red oxide of iron is also quite abundant.

An interesting rock which was examined is the greenish calcareous sandy shale of the Amnicon formation, found on Middle River (see p. 66, Plate VII, p. 50, and Plate XVI, A, p. 72). In the thin section, calcium carbonate was found to separate the very fine angular quartz grains, but on analysis this proved to be less than 20% of the rock. These ripple-marked and mud-cracked shales are interbedded with and merge into red noncalcareous shales and sandstone. Red spots also occur within the greenish rock and greenish within the red. It cannot be determined whether or not the calcium carbonate is original or has been introduced into the rock by underground waters from the adjacent traps.

The following chemical analyses are the only ones available for Wisconsin; unfortunately they mainly represent the Nonesuch formation, which is wholly composed of basic debris; none are typical of the great body of the group:

ANALYSES OF SANDSTONE OF THE ORONTO GROUP.[1]*

Locality.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	CO_2	Total
NONESUCH FORMATION									
Bad River	54.50								
Bad River	49.14								
Montreal River	55.91								
Bad River (shale)	51.98								
FREDA SANDSTONE									
Bad River	75.24								
White River Falls	68.91								
AMNICON FORMATION									
Bad River Falls	69.78	15.43	7.93	.49	1.17	2.64	2.42		99.86
Bad River Falls	72.14								
Middle River				10.71	.12			8.55*	

* Calculated.

[1] Geol. of Wis., 1873–9, vol. III, p. 203. Last by Victor Lehner, 1911.

EILEEN FORMATION, SOUTH FORK OF FISH CREEK, SEC. 19, T. 47, R. 5 W., TOWN OF EILEEN, BAYFIELD COUNTY.

A. Vertical beds of red and white streakel feldspathic sandstone, showing horizontal joints (see Plate X, B, p. 56). The strike is nearly east and west.

B. Vertical beds of red and white sandstone and sandy red shale. Looking southwest.

Bedding. The bedding of the Oronto Group varies from shaley to layers several feet in thickness (Plates VII, p. 50; VIII, p. 52, XI, p. 58; XVII, A, p. 74); but in general it is thinner and more regular than that of the Bayfield sandstones. However, the difference may in part be accounted for by the fact that the exposures of this group are smaller; and being of steeply-inclined layers, they expose to view less of the horizontal variability of the beds. A very striking feature of much of the group is the extremely rapid variations from very coarse grit or conglomerate to fine shale. Shale is very often interbedded with conglomerate through a considerable thickness of strata, the sharpness of contacts and scarcity of sandstone being remarkable (see pp. 62, 106). Cross-bedding is abundant, but usually small; no prevailing direction of dip was discerned. Curved beds are often met with, some being shown in Figs. 6,

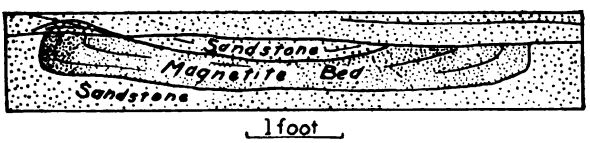


FIG. 6. Magnetite sand bed in Eileen sandstone, Fish Creek, Bayfield County.

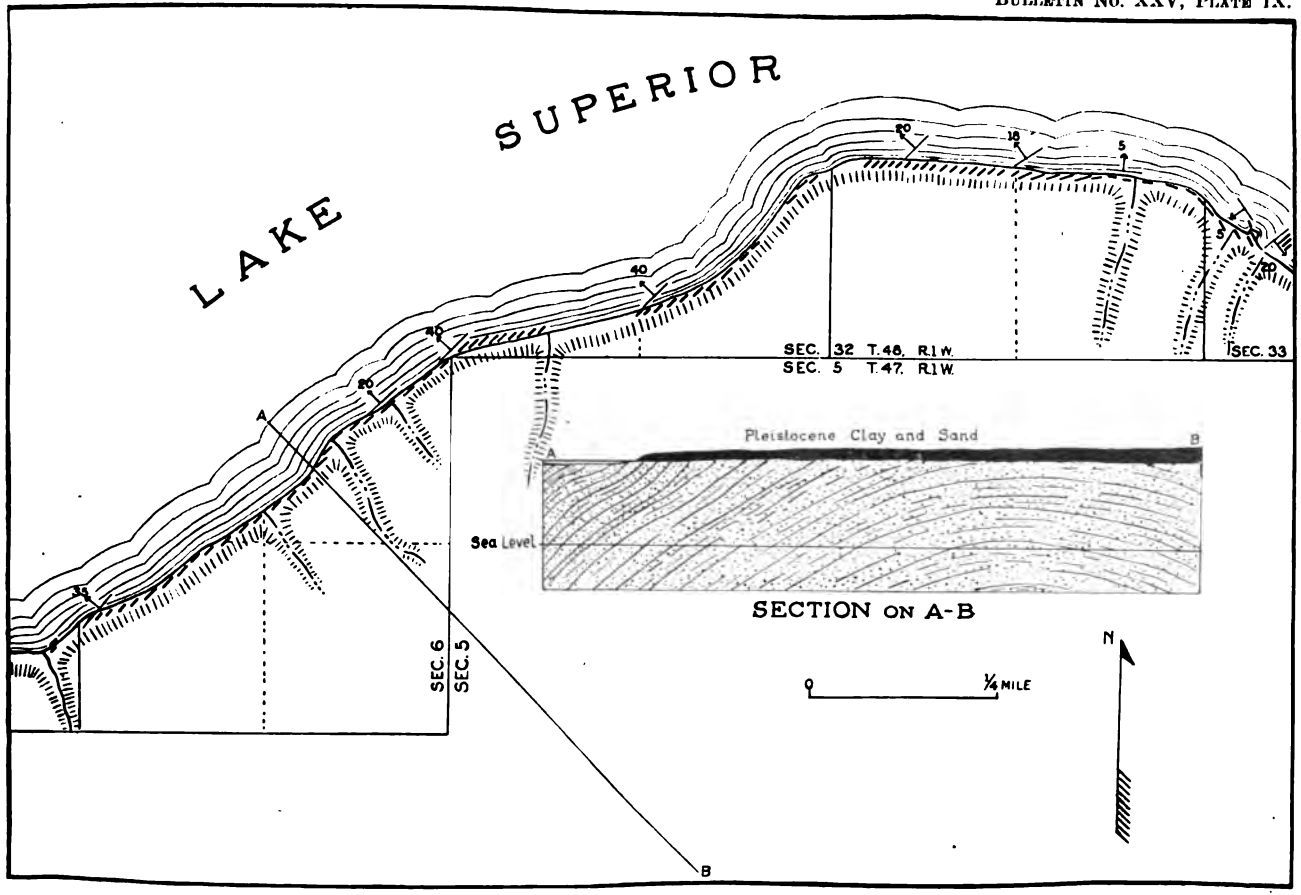
and 7, p. 55. Channels in the top of shale beds, filled with sandstone, are very common; an example is given in Fig. 9, p. 69. Ripple marks are very abundant, being mainly of the symmetrical type and rather small in size (see Fig. 4, p. 40). These occur in the finer grained rocks, especially shales, the surfaces being often greenish or red shale, or decidedly ferruginous sandstone. In some localities mud cracks are extremely abundant; but they are readily overlooked, for they do not show on weathered surfaces. This remark also applies to rain prints, which were observed at but one point. Frequently none of these features are of such character that they may be utilized to determine the top of the strata. In the case of mud cracks, the filling often adheres to the nearest hard sandy layer, whether it is above or below the original surface. When developed in typical form, cross-bedding is the most reliable guide to the structure (see Fig. 8, p. 63 and Plate XIc, B, p. 64). Clay pockets and scattered pebbles are not common. Most of the former are of the small flattened type and grade into small lenses of shale. Veins of calcite are abundant.

LOCAL DETAILS

Amnicon Formation. The top of the Amnicon formation may be observed on Fish Creek, near Ashland, and on Middle and St. Louis rivers in Douglas County. These interesting exposures and their correlation will be described in the succeeding chapter. Aside from these the highest known beds are those seen at the lower falls of Bad River, in sec. 25, T. 47, R. 3 W. About 750 feet of greenish and red coarse arkose sandstone, with interbedded red shales, are there exposed.[1] Microscopic examination shows that the rock is composed mainly of small fragments of porphyry, although the debris of basic rocks is also seen. This is confirmed by the chemical analysis on p. 52. In some beds considerable quartz is seen. The section is probably near the base of the formation.

Eileen Sandstone. In secs. 20 and 21, T. 47, R. 5 W., Town of Eileen, Bayfield County, the valley of the South Fork of Fish Creek exposes about 1800 feet of sandstone in vertical beds. The bedding varies from heavy to shaley with a little clay shale as shown in plate VIII, p. 52. The colors range from brick red, or occasionally even deeper shades, to clear white and show much mottling and banding of red and white. Beds composed almost exclusively of magnetite are also seen. Some are as much as eighteen inches in thickness but have only a slight lateral extent. Ripple marks, cross-bedded and irregularly bedded or domed beds occur, as shown in Figs. 6 and 7. Pebbles are not very common. Microscopic examination (Plate X, B, p. 56) shows that only a third of the rock is quartz. Feldspars (mainly orthoclase with some microcline and plagioclase, more or less altered), magnetite, mica, iron oxides, and rarely altered ferromagnesian minerals make up the larger portion of the rock. The grains are decidedly angular, as is usual in all the sandstones of the region. Were it not for the structural relations, however (see

[1] Irving, R. D., Geol. of Wis., 1873–9, vol. III, pp. 14, 202; Copper-Bearing Rocks, Mon. U. S. G. S., vol. V, p. 132. Irving states that 2000 feet of strata were then seen, but the writer was able to find but the one exposure, about three-eighths of a mile long. No map of the river is accurate.



Outcrop map of Clinton Point, Iron County. Most of the ledges shown on this map, are covered at high water. Those showing southeasterly dips can be seen only from the top of the bank, as they are in water several feet deep. The rocks are arkose sandstones and red shales, undoubtedly belonging to the Oronto group (see Plate X, A, p. 56), although once correlated with the Bayfield group.

section, p. 63, and structure sections on map) these rocks might be regarded as the lower part of the Orienta formation.

On the west side of Clinton (locally known as Marble, or sometimes Graveyard) Point, are low ledges dipping at a moderate angle to the northwest, exposing some 1,300 feet of fine-grained and somewhat shaley to heavily bedded sandstone (Plate IX, p. 54). In general character, it most resembles the last described beds and so is correlated with them. It is, however, not greatly different from the rocks exposed on Bad River (see p. 54). Ripple marks, cross-bedding and contorted

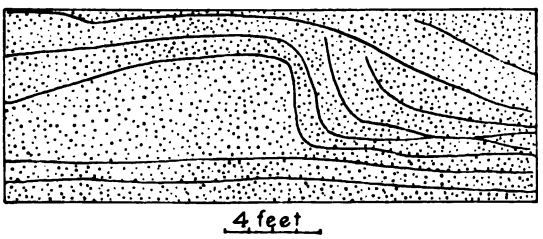


FIG. 7. Bedding in Eileen sandstone, Fish Creek, Bayfield County.

bedding, as well as indistinct mud cracks are observed. A thin section (Plate X, A, p. 56) from a representative phase shows not over a quarter of the rock to be quartz; the remainder is feldspar, about half orthoclase and half plagioclase, as well as ferromagnesian minerals and micas.[1] The minerals show considerable secondary enlargement. The cement is quartz, feldspar, and calcite. These rocks were formerly correlated erroneously with the Bayfield Group (see pp. 15, 18).

At Mason, in eastern Bayfield County, the well at the mill of the White River Lumber Co. penetrates, beneath 145 feet of drift, 650 feet of sandstone with occasional beds of red sandy shale, presumably belonging to the Eileen formation.

Freda Sandstone. Below the dam across White River, in sec. 6, T. 46, R. 4 W., is an exposure of some 300 feet of strata, as shown in Plate XI, B, p. 58. This rock consists of coarse, red and greenish arkose alternating in rather thin beds, with red

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[1] Irving, R. D., Geol. of Wis., 1873-9, vol. III, pp. 16, 209. Copper-Bearing Rocks, Mon. U. S. G. S., vol. V, p. 366.

Lane, A. C., and Seaman, A. E., Geol. Section of Michigan, Report State Board of Geol Survey of Mich., 1908, p. 33.

and green micaceous shales. Some poorly developed ripple marks and mud cracks were observed. Lithologically, this section might be assigned either to the horizon of the Bad River rocks, or to the top of the Amnicon formation, as seen on Fish Creek five miles to the north (see p. 62); but on structural grounds (see section E-F on general map) it is simpler to assume that it lies at the top of the Freda sandstone, in the gap between the Oronto Bay and Fish Creek sections (see p. 50)[1]

In the valleys of the streams that flow into Oronto Bay, in Iron County, occur numerous excellent exposures of the Freda sandstone (Plate XI, A, p. 58). The prevailing rock is red, fine grained arkose. Some thin greenish beds occur. There are also numerous beds, usually rather thin, of markedly micaceous red shale. Toward the base of the formation, the grain becomes coarser, and there is found a 100-foot layer of conglomerate. The exposures represent a thickness of over 12,000 feet, but they are separated into two groups, with an unexposed interval of some 4,000 to 5,000 feet of stratigraphic thickness. As assumed in the case of the other interval of no outcrops, it is most probable that the lack of exposures is due to the softness of the rock (see p. 21). Microscopic examination[2] shows that less than a fourth of the rock is quartz, the bulk being feldspars and fragments of porphyries and basic eruptives with reddish decomposition products, micas, ferromagnesian minerals, and magnetite. The cement is usually red oxide of iron,[3] but in some cases it is calcium carbonate, and to some extent quartz. The quartzes and feldspars show secondary enlargements.

The Freda sandstone is also exposed on Potato River, within the area of the map, but this locality was not visited by the writer.[4]

Nonesuch Formation. Exposures of the Nonesuch formation of the Oronto group occur on the Montreal, Oronto, and

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[1] Irving, R. D., Geol. of Wis., 1873–9, vol. III, pp. 14, 202.

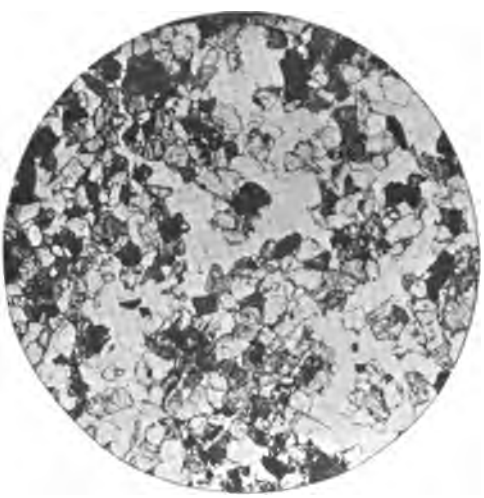
[2] Irving, R. D., and Chamberlin, T. C., Observations on the Junction between the Eastern Sandstone and the Keweenaw series on Keweenaw Point, Lake Superior. U. S. G. S. Bull. 23, 1885, p. 82.

[3] Irving, R. D., Geol. of Wis., 1873–9, vol. III, pp. 12, 199. Copper Bearing Rocks, Mon. U. S. G. S., Vol. V, pp. 133, 226.

[4] Irving, R. D., Geol. of Wis., 1873–9, vol. III, pp. 188, 202.

PHOTOMICROGRAPHS IN ORDINARY LIGHT, MAGNIFIED 12 DIAMETERS.

A. Fine-grained arkose sandstone from Clinton Point, Iron County (specimen 11,124). The grains run from .1 to .3 mm. in diameter. About 25 per cent are quartz. The remainder is about half orthoclase, the other half being microcline, plagioclase, ferromagnesian minerals, mica, and iron oxide. Calcite is in some places seen forming a cement. Most of the cementation is, however, due to enlargements of the quartz and feldspar grains. This section should be compared with those of the Bayfield group shown in Plates III, p. 26, and VI, p. 44, the rock having formerly been placed in that group.



B. Medium-grained red sandstone from Eileen formation on South Fork of Fish Creek, Bayfield County (specimen 11,369). This rock differs mainly from A, in the size of grains, which average nearly .3 mm. About a third of the rock is quartz, the remainder being mainly orthoclase. Some plagioclase, micas, and ferromagnesian minerals are found. The large white areas are holes in the section.

Potato rivers. This member is composed of red, gray and black arkose and shale, often with calcareous cement. Microscopic examination shows that the rocks are composed of virtually unaltered debris of basic eruptives. The thickness on Montreal River is about 350 feet, lessening rapidly to the west.[1]

Outer Conglomerate. Beneath the Nonesuch shale is found the great Outer Conglomerate, which is 1,200 feet thick on Montreal River, but thins to only 800 feet on the Potato. On the former stream, it outcrops in magnificent cliffs over 200 feet in height. The conglomerate is composed of pebbles averaging four or five inches in diameter—some measure fifteen inches or more. They are from the diabase, porphyry, gabbro, and other rocks of the Middle Keweenawan series, with subordinate amounts of Huronian quartzite, iron formation, slate, and chert, as well as granite and vein quartz, probably derived mainly from the Archean. There is practically no matrix of sand, and the bedding is only apparent where there are thin layers of coarse arkose sandstone. As in the higher beds, calcite veins are common.[2]

OLDER FORMATIONS

The Traps. Beneath the base of the Outer Conglomerate is found a great series of interbedded traps, conglomerate, sandstone, and shale. This reaches a thickness of some 1,200 feet on the Montreal, but to the southwest thins out to nothing within a few miles. Below this occur the traps of the Middle Keweenawan, including both extrusive and intrusive rocks. These rocks also occur in the Douglas Range.[3]

The Pre-Keweenawan Rocks. Still farther to the southeast, the Huronian sediments are found in a position stratigraphically below the eastern traps; and then in turn the older Archean granites, schists, and greenstones (see p. 7).

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[1] Irving, R. D., Geol. of Wis., 1873–9, vol. III, p. 200. Copper Bearing Rocks, Mon. U. S. G. S., vol. V, 1883, pp. 133–226.

[2] Irving, R. D., Geol. of Wis., 1873–9, vol. III, pp. 12, 202.

[3] In S. E. ¼ of N. E. ¼ sec. 19, T. 47, R. 4 W., near Ashland, a huge mass of trap 60 feet across rises from the clay plain. As no rock is found in neighboring wells, the writer believes that this is simply an enormous boulder, and not an outcrop as believed by some.

Economic Products. So far as known, no products of economic value are found in the Oronto group. In contrast to the earlier sedimentary series of the Lake Superior region, it contains no iron formation. Thin lenses of nearly pure magnetite occur in places, especially along Fish Creek; but they are hardly greater in amount than the magnetitic sands of the modern lake beaches, or the drift. Most of the rock, with the possible exception of parts of the Eileen sandstone on Fish Creek is entirely unsuited for building stone. Occasionally, however, some of the red shale has been used for paint rock. Traces of copper and silver have been found in the Nonesuch formation,[1] but no concentration of these minerals or the abundant ferric oxide is known to have taken place in Wisconsin.

The rocks of the Oronto group carry little water and such little as is found is often salty (see pp. 66, 73, 102).

The Extension of the Sandstone Groups into Minnesota. The Bayfield and underlying Oronto groups of sandstones extend into Minnesota, as shown by Hall[2], between the continuation of the Douglas Trap Range to the southeast and the Huronian and Archean rocks to the northwest. The drift is so thick along this narrow strip, however, that the actual continuity with the Paleozoic sediments to the south is somewhat doubtful.[3] Nevertheless, a brief discussion of this question is not out of place.

Most of the rock exposed in this belt is a well indurated, rather fine to medium grained, quartz sandstone pinkish to yellow or gray in color. This, the rock of the well known quarries of the Kettle River region, is much like the sandstones found near the falls of Black River in Douglas County[4] (see p. 45).

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[1] Irving, R. D., Geol. of Wis., 1873–9, vol. III, p. 206.

[2] Hall, C. W., Keweenawan Area of Eastern Minn., Bull. Geol. Soc. America, vol. XII, 1908, p. 313.

[3] Grout, F. F., personal communications.

[4] Grout, F. F., personal communications.

Weidman, S., personal communications.

It may not be too great a stretch of the imagination to suggest that these light colored rocks may be equivalent to the Devils Island sandstone of the Apostle Islands.

A. Red and greenish arkose sandstone and shale of Freda sandstone, on east bank at mouth of Oronto River, Iron County.

B. Red and green shale and arkose grit of Freda formation, below dam of White River electric plant, Sec. 6, T. 46, R. 4 W., Ashland County. The northeasterly strike is plainly indicated by the outcropping ridges; the dip is 25 degrees to the southeast, away from the observer.

Still farther to the south and southeast, in the valley of the St. Croix River, appear flat-lying, yellowish or pinkish quartz sandstones, bearing fossils of Upper Cambrian age. These rocks (the Potsdam sandstone of Wisconsin) rest with pronounced unconformity upon both the tilted traps of Keweenawan age and the older Pre-Cambrian rocks. The known Cambrian rocks are separated from those of the Kettle River district by a considerable drift-covered interval, probably underlain largely by trap and granite, as well as by the great fault of the Douglas Range which is known to extend far into Minnesota, forming the northwestern border of the traps.[1]

In many places deep drilling has shown that the Potsdam rests upon a great thickness of red clastic rocks. These red rocks fill a great depression in the surface of the Pre-Cambrian crystalline rocks.[2] The thickness of these red rocks varies from nearly 2,500 feet in the center of the basin down to nothing at both sides of the trough and to the south, where the Potsdam rests directly upon the Pre-Cambrian igneous and metamorphic rocks. But few wells have penetrated the entire thickness of the red clastic series near the center of the basin. At Minneapolis they are found to rest upon granitic rock, while at Stillwater, apparently at the center of the trough, Keweenawan diabase lies beneath (see p. 60).

The red series is studied with difficulty as it is not known to reach the surface. The only information is derived from churn drill records and is hence rather unsatisfactory. N. H. Winchell[3] believed they were a conformable connection of the Cambrian with the Keweenawan. More recently C. W. Hall restudied the question, reaching the same conclusion (see p. 20).[4]

The red clastic series consists of red shale and sandstone while some fragmental volcanic rocks are thought to exist. The sand-

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[1] Hall, C. W., Keweenawan Area of Eastern Minn., Bull. Geol. Soc. America, vol. XII, 1901, p. 313.

[2] Hall, C. W., Meinzer, O. E. and Fuller, M. L., Geology and Underground Waters of Southern Minnesota, U. S. G. S. Water Supply Paper 256. 1911, pp. 32, 48.

[3] Winchell, N. H., Geol. of Minn., vol. I, 1882, pp. 422, 424, 537.

[4] Hall, C. W., The Red Sandstone Series of S. E. Minn. Unpublished manuscript not available. Abstract, Science, vol. 27, 1908, p. 722.

stone is mainly composed of quartz grains, but much of it contains more or less feldspar and is very frequently calcareous. It is not always red, for occasionally white sand is reported.

The following record of the well at Stillwater gives a good idea of the lithologic character of the series:

LOG OF STILLWELL DEEP WELL [1]

		Thickness
Pleistocene		
Glacial drift		18 feet
Cambrian		
Mendota limestone		85
Potsdam sandstone; calcareous sandstone of gray to yellowish color and some gray shale		592
Upper Keweenawan		
Dark red, sandy calcareous shale	13	
Coarse quartz sandstone	5	
Fine dark red calcareous shale	11	
Fine dark red calcareous sandstone with some calcite and pink feldspar grains	2233	2262
Middle Keweenawan		
Diabase		450
Depth of Well		3447 feet

In general, these rocks are exactly like those of the Upper Keweenawan series of the Lake Superior basin, whose continuation they must be; while beyond doubt the basin in which they lie is part of the Lake Superior syncline which passes up Chequamegon Bay, and thence southeasterly across Wisconsin (see p. 88). The portion in southeastern Minnesota is probably everywhere separated by the traps of the north side of the basin, from the belt northwest of the fault in which lies the lighter colored

[1] Hall, C. W., Meinzer, O. E. and Fuller, M. L., Geology and Underground Waters of Southern Minnesota, U. S. G. S. Water Supply Paper 256, 1911, p. 366.

Meads, A. D., The Stillwater Deep Well. Bull. Minn. Acad. Nat. Sci., vol. III, No. 2, 1891, pp. 274–7.

Winchell, N. H., Natural Gas in Minnesota. Minn. Geol. and Nat. Hist. Survey, Bull. V, 1889, p. 25.

sandstones of the Kettle River region. A connection west of the fault, through the heavily drift-covered region of Anoka County, Minnesota, is nevertheless possible.

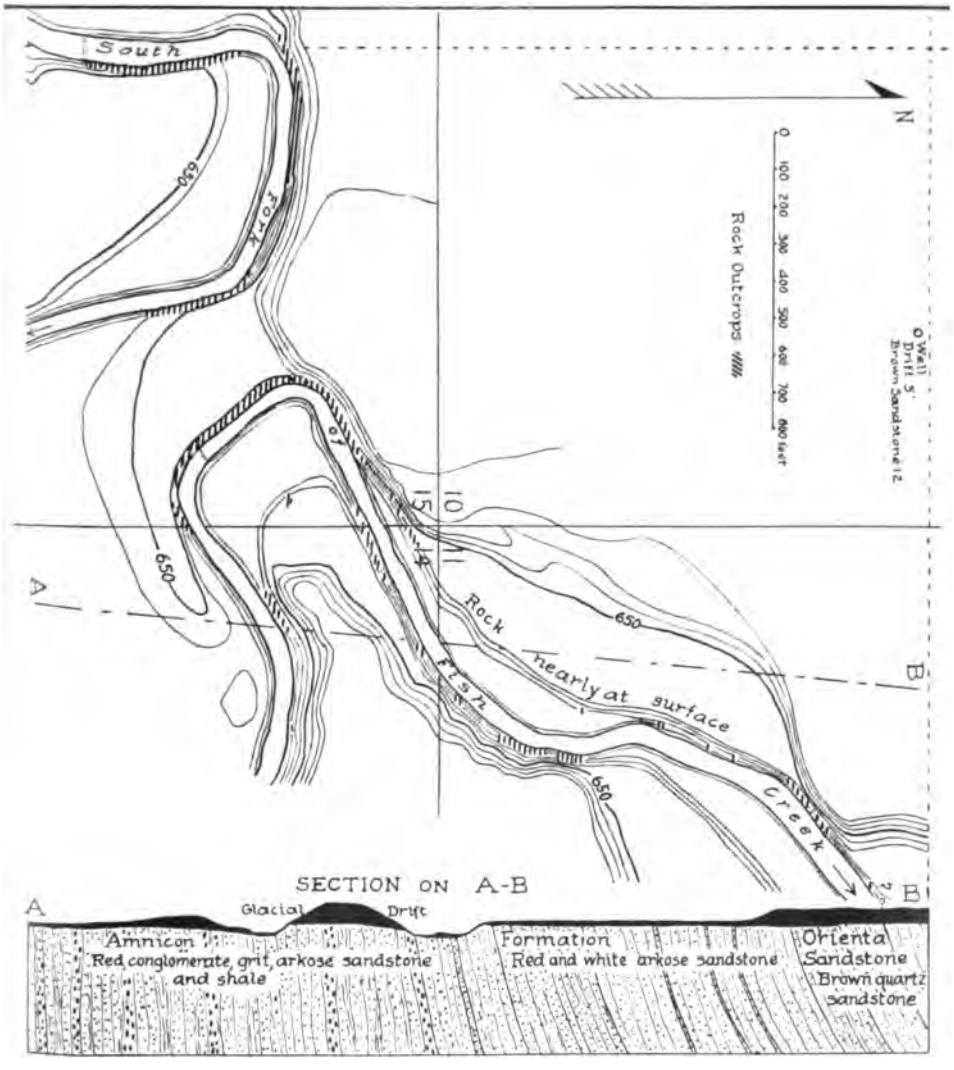
Whether or not these buried red rocks are conformable beneath the Upper Cambrian marine sediments is a question beyond the scope of the present report. On the whole, the ocurrence of the red series in a basin, overlapped on both sides by the overlying horizontal sediments which rest with pronounced unconformity upon the tilted Keweenawan traps, favors the view that an unconformity also exists between the sandstones (see p. 103). Such an unconformity probably could not be recognized in the records of churn drill holes.

CHAPTER V

THE RELATION OF THE BAYFIELD AND ORONTO SANDSTONE GROUPS

General Statement. The study of the relation of the Oronto and Bayfield groups of sandstones was the principal object of the present investigation. Outcrops are so scarce that we can at no place trace the two sandstone groups to a point of contact where their relations may be absolutely determined. But it is possible to find exposures at points where we should expect to to find the contact of the Bayfield and Oronto groups. At all of these localities there is a conformable gradation from quartz sandstone of the general type of the Bayfield group downward into red shales, and arkose sandstone or conglomerate of the same general type as the main body of the Oronto group. Sections showing this general stratigraphic succession are found on the south fork of Fish Creek, near Ashland, not far from the main area of the Oronto group, in the deep well at Ashland, on Middle and St. Louis rivers in Douglas County, and in deep wells in Superior. This widespread stratigraphic sequence shows a gradation between the two general types of sandstone formations and is believed to indicate that the Bayfield and Oronto groups are conformable.

Fish Creek. Beginning at the east, there is found an exposure of the supposed base of the Bayfield group, in the town of Eileen, near Ashland Junction, in eastern Bayfield County. Here the valley of the South Fork of Fish Creek exposes rock in sections 11, 14, and 15, T. 47, R. 5 W. These exposures have never been described previous to the present study. The beds are ver-



Plane-table map (10-foot contours) of rock exposures on South Fork of Fish Creek, Secs. 11, 14 and 15, T. 47, R. 5 W., Town of Eileen, Bayfield County. The exposures are thought to represent a conformable gradation from the red conglomerates and arkose sandstones of the Amnicon Formation of the Oronto group, to the brownish quartzose sandstones of the Orienta sandstone of the Bayfield group.

tical or inclined steeply to the north, decreasing from 90° at the south to 70° at the north end of the section, while the strike is approximately east and west (see p. 93). (See Plates XI b, p. 62, and XI c, p. 64). The following section is based upon a chained

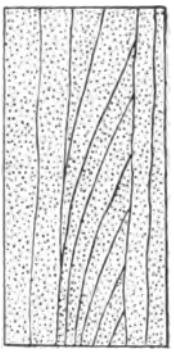


FIG. 8. Diagram showing the use of cross-bedding, in determining top of vertical strata. The top is to the right.

plane table survey made by the writer in 1912, as shown in Plate XI a. The thickness are therefore accurate. Although the exposures are not continuous, the rock is everywhere so near the surface that abundant fragments permit the general character of the strata to be determined.

SECTION ON SOUTH FORK OF FISH CREEK, BAYFIELD COUNTY

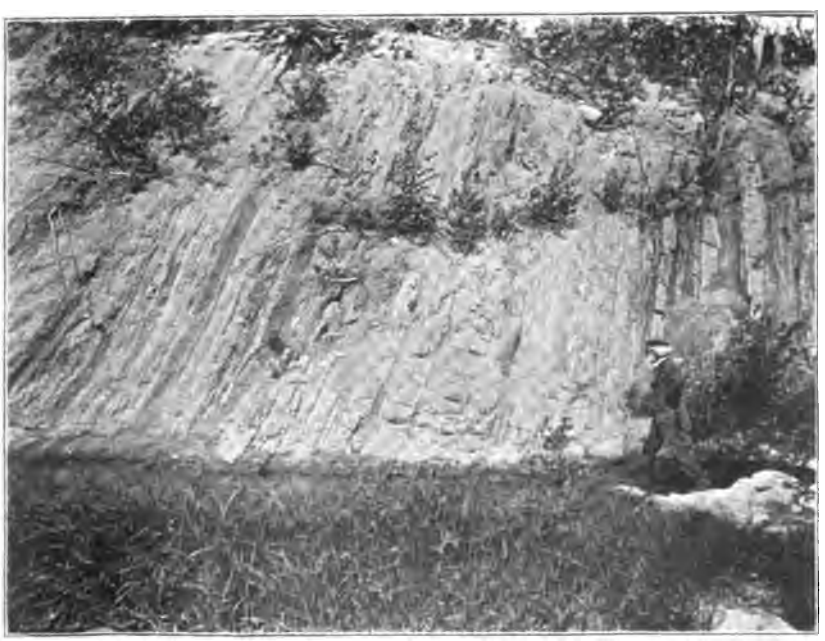
Bayfield Group: Orienta Sandstone.	*Thickness* Feet.
14. Heavy to thin-bedded medium grained brown quartz sandstone. often cross bedded. This rock is of the typical Bayfield type, being apparently *nearly all quartz*, but with some mica flakes and feldspar grains. Is pebbly in places	50
13. Red and white spotted, thin to medium bedded and cross bedded quartzose sandstone. A thin section (Plate XII, p. 66) shows that *three quarters of the rock is quartz*, the remainder being mainly orthoclase	75
12. *Unexposed*, but shows abundant fragments of red grit and coarse red and white sandstone . . .	150
11. Red grit in small ledge	5
10. *Unexposed*, but shows fragments as before . .	65

9. Red grit in place	5
8. *Unexposed*, but shows fragments as before	130
7. Red grit and red and white sandstone	10
6. *Unexposed*, but shows fragments as before	190
5. Medium to heavily bedded coarse brownish red and white (often in spots) sandstone with red and greenish shaley partings and some red grit. A thin section from the coarse sandstone, with minute layers and pockets of shale, shows that it is not greatly different from the higher strata. Most of the feldspar is orthoclase but some microline, plagioclase, and mica are seen. Most of the section (Specimen 11401) is red shale composed of fine grains of quartz cemented by iron oxide and the decomposition products of feldspars, etc. A thin section (Plate XII, B) from the coarse white sandstone shows that *less than half the rock is quartz.* The grains are angular and vary from 2. mm to below .25 mm in diameter. Mica is abundant	230
4. *Unexposed*, but shows fragments of rock like the last	100
3. Thin to medium bedded shaley to gritty red and white sandstone	15
2. *Unexposed*, but shows fragments like the adjacent rocks	85
Oronto Group: Amnicon Formation.	
1. Coarse red and white spotted arkose grit. Conglomerate with pebbles seldom over 3 inches in diameter of trap, vein quartz, quartzite, slate, iron formation, and chert. The beds vary from a foot to 15 feet in thickness with subordinate layers of coarse arkose sandstone and red and greenish shales. There is some cross bedding (see Plates XIb, XIc)	1,050
Total thickness	2,160

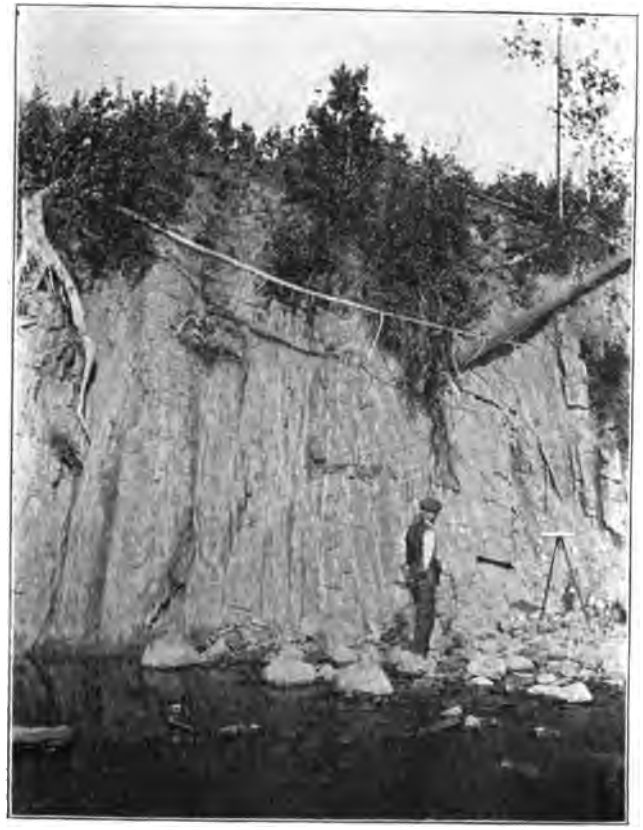
An unexposed interval of nearly 5,000 feet separates this section from the outcrop of the Eileen sandstone in Secs. 20 and 21.

This section is quite important, since it throws new light on the structural relations of the sandstone groups. It is but five miles from the area of rocks undoubtedly belonging to the Oronto group. The lowermost beds of this section are as highly tilted as any of the recognzied Oronto group, and match it ex-

A. General view, looking southeast, on South Fork of Fish Creek, NE ¼ of NE ¼, Sec. 15, T. 47, R. 5 W., Bayfield County. The rocks are red conglomerate and grit, with some red shale, and are correlated with the Amnicon formation. The dip is to the north and varies from 70° to 90°, while the strike averages N. 85° W.



B. Exposures upstream from A, looking east. The rocks are the same, but with more layers of red shale.



A. Vertical beds of Amnicon Formation, on South Fork of Fish Creek, Bayfield County. The rock is conglomerate and grit, red in color, but with some streaks and spots of white. There are also partings of red shale.

B. Cross-bedding in red and white grit, near the place shown in A. By means of cross-bedding, it may be determined which was the top side when the strata were still horizontal. In this case it may clearly be seen that the cross-bedded layers merge into the others at the right or south side, while they are sharply cut off by

actly in lithologic character. The anticline of which they form part of the north limb involves at least 8,000 feet of strata. This fold must belong to the general system of Keweenawan folds (see p. 95), since there is no known subsequent period of deformation with which it could be correlated. The correlation of the lower horizons of the Fish Creek section with the Oronto group seems therefore to be very well established.

The correlation of the upper quartzose beds with the Bayfield group is much less definite. A drift-covered interval of about three and one-half miles exists between the most northerly exposure on Fish Creek and the outcrops of the Chequamegon sandstone on Wayman Point. This belt was carefully explored but no exposures could be discovered, and the inhabitants of the region unite in saying that none exist. The evidence on which the upper layers are correlated with the base of the Orienta sandstone depends on three factors:

1. The lithologic likeness is complete and can be better appreciated in the field than in a description. The bedding is also characteristic of the upper group, being frequently very heavy, but giving way rapidly to thin cross-bedded layers.

2. The dip of the beds decreases towards the north end of the section, thus indicating a probable flattening out of the beds to the north (see structure section E-F, on map).

3. The deep well at Ashland encounters a very similar succession of beds to that shown in the section on Fish Creek, and indicates a pronounced flattening of the beds to the north.

Ashland Well. At the plant of the Lake Superior Iron and Chemical Company in Ashland three miles to the northeast of Fish Creek, is a well 3,095 feet in depth. Although not situated in direct line between the most northerly exposure on Fish Creek and the nearest exposures on the northwest shore of Chequamegon Bay, nevertheless if the position of the well is projected parallel to the probable strike of the rocks, it will be found to occupy a position well to the north of the Fish Creek exposures, thus serving very well to fill in the unexposed interval. If the red shales there encountered represent even approximately the horizon of those seen on Fish Creek, from which they differ only in lacking the conglomerate beds, a flattening out of the beds

toward the north is indicated (see structure section E-F). While it cannot be positively stated that any of the beds encountered in the well belong to the Bayfield group, it is nevertheless shown that the usual stratigraphic succession of sandstone grading down into red shales is here found.

LOG OF "JUMBO" WELL AT ASHLAND

Drilled in 1889 at works of Lake Superior Iron and Chemical Company, near west ¼ post of Sec. 5, T. 47, R. 4 W. Elevation of curb, 660 ft. A. T. Record from original log, furnished by Mr. J. E. Johnson, Jr., manager, 1910.

	Thickness Feet	*Depth* Feet
Pleistocene:		
Red clay	40	
Till with boulders	43	
Red sand	92	175
Bayfield Group: Orienta Sandstone.		
Principally fine grained sandstone of red color with few white beds, and bands of red shale from one to ten feet thick. A soft stratum 30 feet thick, 82? feet from the top, furnishes most of the water. The flow did not increase below it. The water is said to be salty	2,495	2,670
Oron'o Group: Amnicon Formation.		
Red shale	425	3,905
Depth of well	3,095	3,095

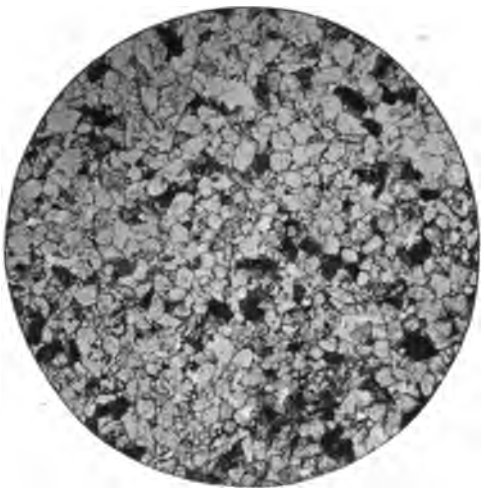
Middle River. On Middle River, in eastern Douglas County, occurs perhaps the most interesting exposure in the entire district. Here over 3.000 feet of strata are exposed in a great overturned fold. The structure of the locality is shown in Plate XIII, p. 66, which is based on a paced survey made by Grant in 1899.[1] (See also Plate VII, p. 50; Plate XVII, B. p. 74; and Plate XXI, 90).

[1] Grant, U. S., Copper-Bearing Rocks of Douglas County, Wis. Geol. and Nat. Hist., Survey, Bull. VI, 1900, pp. 18, 20.

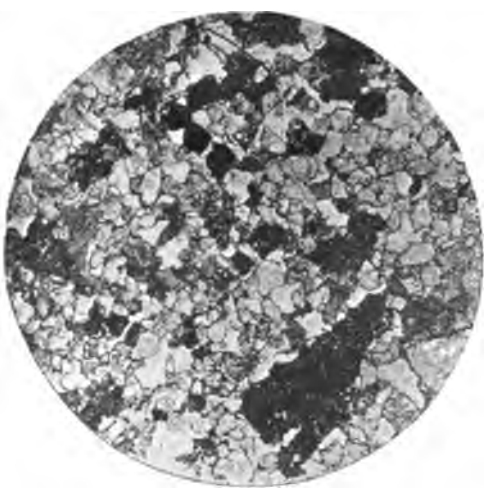
Personal communications.

Sweet, E. T., Geol. of Wis., 1873–9, vol. III, p. 347.

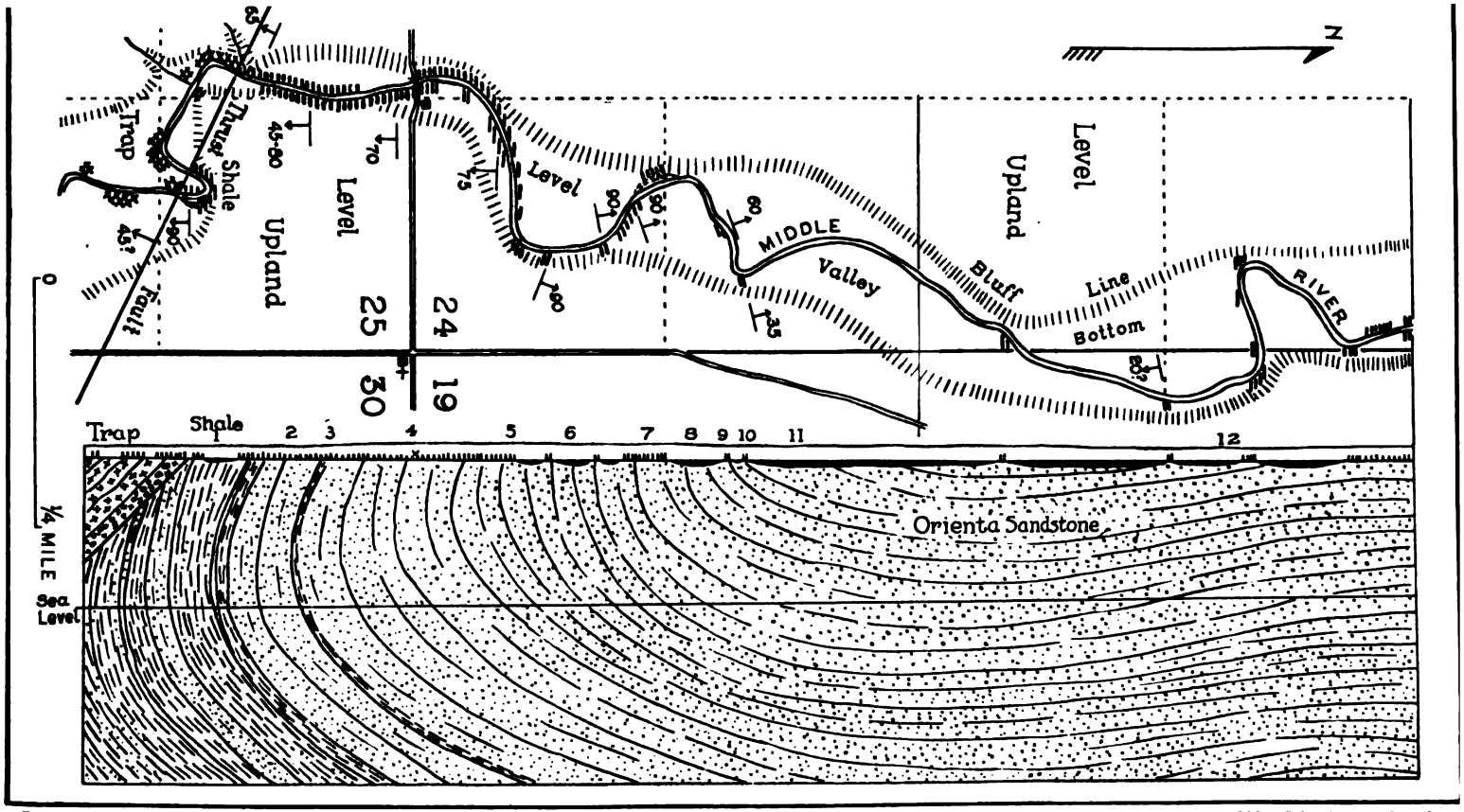
PHOTOMICROGRAPHS IN ORDINARY LIGHT, MAGNIFIED 12 DIAMETERS.



A. Medium-grained feldspathic sandstone (specimen 11,404), from South Fork of Fish Creek, Sec. 11, T. 47, R. 5 W., Bayfield County. Average diameter of grains .35 mm. Seventy per cent of the rock is quartz, the remainder being feldspars (mainly orthoclase, but some microcline) and iron oxide. The cement is quartz. It should be noted that the rock does not differ greatly from those of the Bayfield group, Plates III, p. 26, and VI, p. 44.



B. Coarse-grained white arkose sandstone (specimen 11,397), from a lower horizon than A. The average size of the grains is .5 mm, but the largest (of microcline) is 2.0 mm. long. Quartz makes up half of the rock; the remainder is mainly orthoclase, but there is much plagioclase; little iron oxide is present. The coarseness and angularity of the grains, as well as the greater proportion of feldspar, should be compared with A.



Outcrop map of part of Middle River, Douglas County, based on survey by U. S. Grant, 1899; structure section by F. T. Thwaites, 1910. Ripple marks show that the south-dipping layers are overturned. The numbers are those of the different beds in the section given on p. 67. The lower bed (1) is believed to belong to the Amnicon formation of the Oronto group. A conformable contact between the Bayfield and Oronto groups is thus indicated.

SECTION ON MIDDLE RIVER, DOUGLAS COUNTY

Orienta Sandstone.	*Thickness* Feet
12. Horizontal thick-bedded light pinkish brown sandstone; grains are of medium size and appear to be *mainly quartz.* The banding with red and white (see p. 31) often gives the impression of folds. Estimated thickness	225
11. *Unexposed,* but showing fragments of thick-bedded brown sandstone	100
10. Thin-bedded reddish sandstone apparently *containing a larger proportion of feldspar.* Dips 35° N.	50
9. Coarse white sandstone with pebbles of trap and quartz; some is very calcareous (Spec. 11243) Dips 60° N.	50
8 *Unexposed,* probably contains the Copper Creek beds	300
7. Medium to coarse grained pebbly, brown sandstone; beds very heavy and hard to make out, but appear to be vertical. Shows iron banding. It may correspond to the brownstone of Amnicon River (see p. 43). Grains of feldspar and mica are apparent to the unaided eye. Under the microscope (Specimen 11240), it is seen that these constitute not over a quarter of the rock, the remainder being quartz. Microcline and plagioclase are distinguishable, although most of the feldspar is orthoclase. Biotite is also seen	250
6. *Unexposed*	200
5. Fine grained red sandstone, apparently containing more feldspar and mica than higher beds; coarse, soft, brown sandstone; reddish, medium-grained, more feldspathic sandstone in vertical beds. The coarser rock was examined microscopically (Plate XIV, A, p. 68) and found to be *over two-thirds quartz.* The subangular grains average .35 mm. diameter. Some large microcline fragments were discovered. It is not notably different from the brownstone at Port Wing (see p. 42 and Plate VI, A, p. 44). The cement is alteration products derived from the feldspars	250

4. Medium to fine-grained pinkish or brownish sandstone with frequent greenish bands and spots. Pebbles and clay pockets are not common. Some beds are cross-bedded or show curious curved forms; most are in heavy layers making the stratification difficult to determine (see Plates XVII, B, p. 74 and XXI, p. 90). Towards the base a few thin layers of red shale occur. Two thin sections from the top and bottom of the horizon were examined (Specimens 11233 and 11235). The grains average less than .3 mm. in diameter and are slightly more angular than in higher strata. *Quartz constitutes from a third to a half of the material.* The remainder is almost wholly much altered feldspar, mainly orthoclase. Occasionally microcline is seen, as well as a few altered ferromagnesian minerals and mica. The cement appears to be quartz and feldspar enlargements, with some iron oxide . . 1,000
3. Red shale, dips about 70° S. 10
2. Fine-grained thin-bedded hard red and greenish gray spotted sandstone. Dip varies from 45° S. to 80° S. Under the microscope this is seen to be little different from the lower part of the bed above (Plate XIV, B, opposite). *Less than half is quartz.* The grains average about .25 mm. diameter and are cemented by quartz and feldspar. Microcline and plagioclase may be distinguished in the feldspars but most of them are much altered, generally to kaolin. Ferromagnesian minerals and mica can also be seen 275

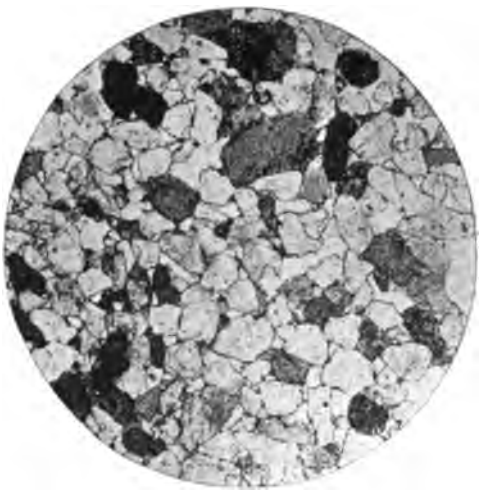
Total thickness of Orienta sandstone 2,735

Amnicon Formation.

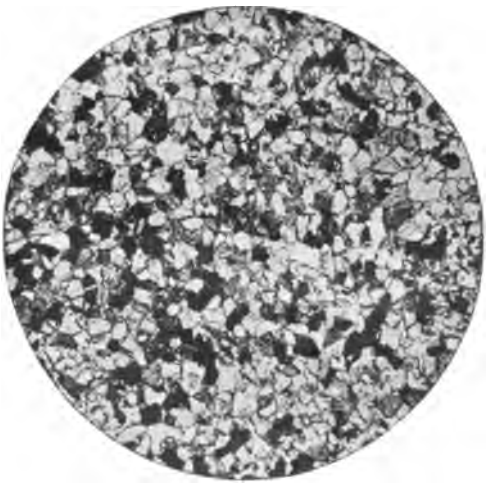
1. Purplish red and light-greenish-gray very fine-grained sandstone to sandy shale, in beds seldom over an inch thick. Dip varies from 60° S. to vertical. Ripple marks and mud cracks are decidedly abundant. There is scarcely any cross bedding. In but one place were found ripple marks by which the inversion of the strata could be demonstrated[1] (see

[1] Most of the ripple marks are of the symetrical indeterminate type.

PHOTOMICROGRAPHS IN ORDINARY LIGHT, MAGNIFIED 12 DIAMETERS.



A. Coarse friable brownstone (specimen 11,236) from bed 5, Middle River, Douglas County. The grains are fairly well rounded as compared with the older sandstones, and average about .35 mm. in diameter. The rock is over two-thirds quartz. The remainder is, as usual, feldspar, in which some large microcline fragments are conspicuous. The cement is composed of alteration products from the feldspars.



B. Fine-grained pink feldspathic sandstone (specimen 11,232) from bed 2. The grains are somewhat more angular than in A, and average .25 mm. in diameter. Less than half of the rock is quartz. Most of the feldspar is orthoclase, but microcline and plagioclase are also abundant. Ferromagnesian minerals, including micas, also occur. The cement is quartz and feldspar, stained with iron. This section should be compared with A, as well as with Plates X, p. 56, and XII, B, p. 66.

p. 90). A thin section (Plate XVI, A, p. 72) from one of the greenish layers was examined. It consists of extremely fine angular grains of quartz (diameter about .01 mm.), with a few feldspars, imbedded in a matrix of crystalline calcite which forms over a third of the slide, but analysis shows that it is less than 20% of the total (see p. 52). Mica flakes are seen in places, being concentrated on some bedding planes. The red noncalcareous phase was not examined microscopically . .	365
Total thickness	3,100

In the field the lithological likeness of the lower beds of this section to the upper part of the known Amnicon formation of the Oronto group is more striking than any description can make it, so that the writer has no reasonable doubt of the correlation as given. However, it must be remembered that the distance from undoubted outcrops of the Oronto group is considerable.

St. Louis River. At the extreme northwest corner of the state, on St. Louis River, and extending for a short distance into Minnesota, is an exposure of about 730 feet of conglomerate, sandstone, and shale. These beds are prevailingly red in color but are spotted and streaked with white or greenish-gray. They contain much feldspar, decreasing in amount towards the top of the section (Plates VI, B, p. 44, and XVI, B, p. 72). Ripple marks, mud cracks, and rain prints are abundant (Fig. 9).

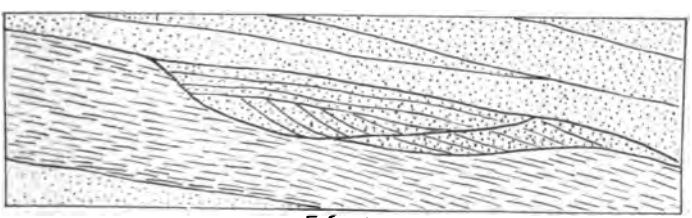


FIG. 9. Bedding in Amnicon formation, St. Louis River, Minn.

In all their characters they are like the upper part of the Oronto group, and insensibly grade upward into rock like that of the lower part of the Orienta sandstone.

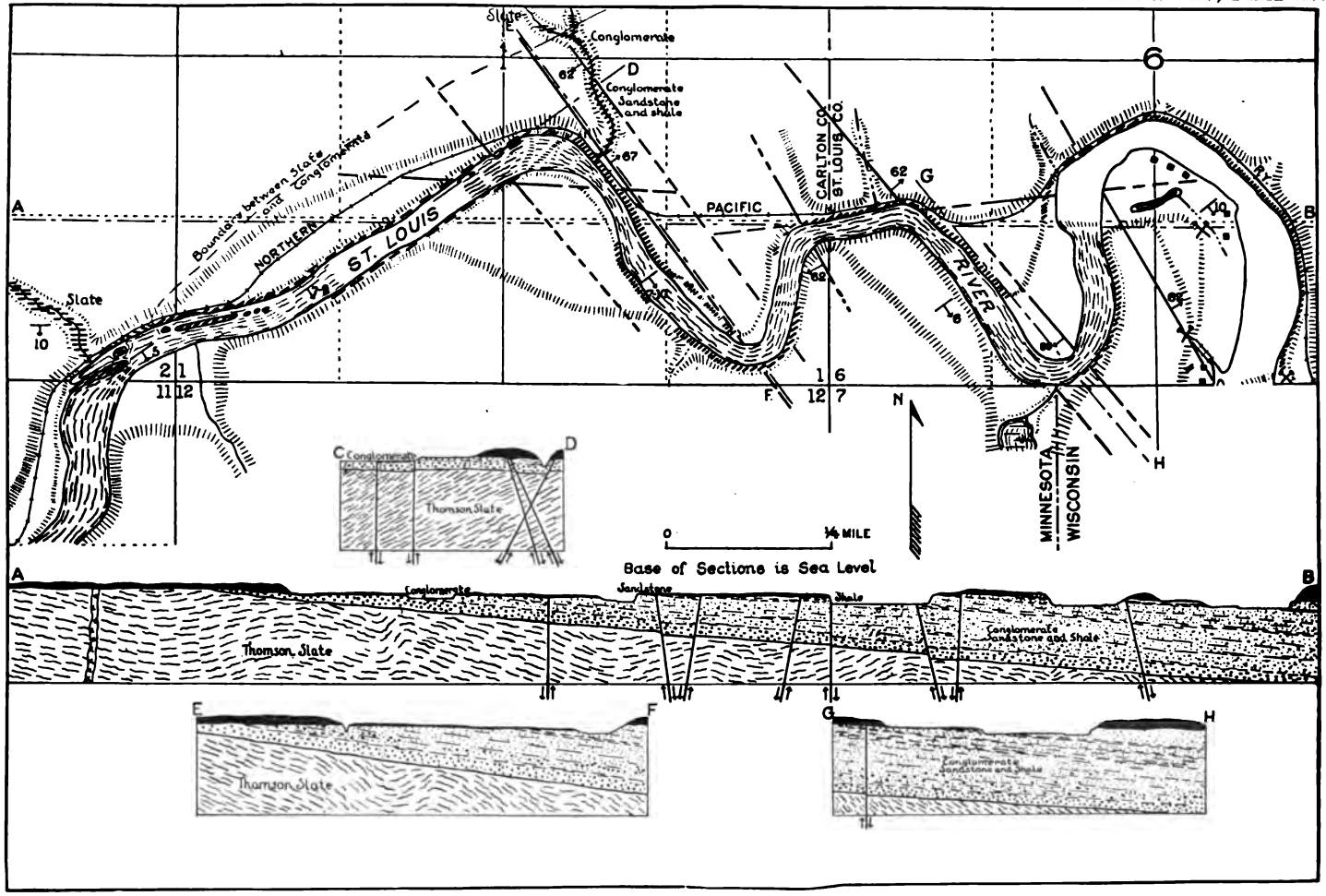
The following detailed section is based upon one given by N. H. Winchell of the Minnesota Survey, supplemented by the observations of the writer.[1] The dip varies from 3° to 10° to the southeast (see Plate XV, opposite).

Winchell was inclined to assume the existence of an unconformity between the lowest conglomerate, which is mainly composed of pebbles of vein quartz, and that which overlies it and is composed of basic trap pebbles. He found a pebble in the latter which he supposed to have been derived from the pyritiferous quartz conglomerate. The writer found no evidence for such a division. A large pebble of Keweenawan porphyry (Specimen 11272) was found in the lower conglomerate, and there is a complete gradation between the two types (see p. 17).

SECTION ON ST. LOUIS RIVER FROM FOND DU LAC TO THE POWER HOUSE

	Thickness Feet
Oronta Sandstone.	
1. Upper Sandstone Beds. Reddish brown sandstone of medium grain (about .4 mm.) spotted with and grading into white. Contains pebbly bands, and micaceous shaley layers. The pebbles are trap, vein quartz, and quartzite. The bedding varies from thick to thin and cross-bedded. The quarries are on this bed. Under the microscope, the grains are seen to be subangular. *About two-thirds of the rock is quartz*, the remainder being more or less altered feldspar, mainly orthoclase (see Plate VI, B, p. 44). Microcline, plagioclase, mica, magnetite, and various ferromagnesian minerals appear. Specks of red iron oxide also appear, but the cement is quartz	200
2. Dark red shale, with greenish layers and spots . .	18
3. Lower Sandstone Beds. Sandstone much like 1. Is somewhat finer grained and contains more mica, shaley beds, red and green clay pockets, and beds	

[1] Winchell, N. H., Amer. Geol., vol. 16, 1895, pp. 75, 150; Minn. Geol. & Nat. Hist. Survey, 10th Ann. Rept., 1881, pp. 30, 91; Id., 23rd Ann. Report, 1894, p. 239; Geology of Minn., 1899, vol. IV, p. 15.


Slate
E
Conglomerate
D
Conglomerate Sandstone and shale
62
67
Boundary between Slate Conglomerate and Sandstone
NORTHERN
ST. LOUIS
R. R.
PACIFIC
CARLTON CO.
ST. LOUIS CO.
62
G
6
A
B
Slate
10
15
2 1
11 12
1 6
F 12 7
N
RIVER
MINNESOTA
WISCONSIN
H
C Conglomerate D
Thomson Slate
0
1/4 MILE
Base of Sections is Sea Level
A
Conglomerate
Sandstone
Shale
B
Thomson Slate
Conglomerate Sandstone and Shale
E
F
Thomson Slate
G
H
Conglomerate Sandstone and Shale

of magnetitic rock. Under the microscope (Specimen 11328) shows little difference from 1, except that *not much over half is quartz* and there is more mica	70
Total Orienta sandstone	288

Amnicon Formation.

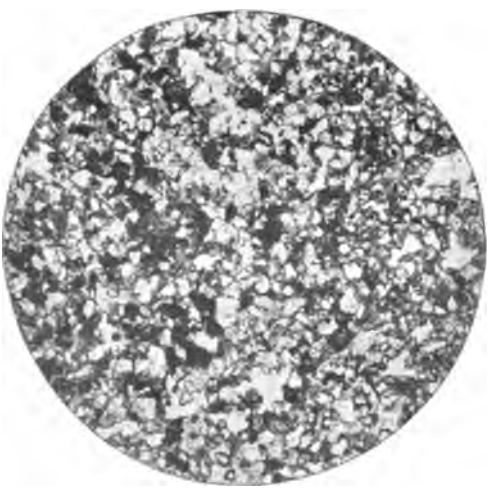
4. Red shale, like 2	10
5. Alternating beds of sandstone and red shale. Thickness not accurately known. Under the microscope (Specimen 11326) shows medium-sized (about .3 mm. diameter) grains; all are subangular. *Not much over half are quartz*, the remainder being mainly altered feldspars of all kinds, orthoclase being most abundant, but some microcline can be distinguished	75
6. Red shale	10
7. Thin-bedded red and white sandstone, finer grained than the higher layers. Under the microscope (Plate XVI, B, p. 72) it is seen that *less than half is quartz*. The orthoclase feldspars are much altered, but some plagioclase was seen. There is considerable mica. The cement is mainly calcite . .	3
8. Main Shale Bed. Red shale with thin partings of hard greenish sandstone, and some grit towards the base. Thickness not accurately known on account of faulting (see Plate XVII, A, p. 74) . . .	45
8M[1]. Red and green shale with ripplemarks . .	4.5
9. Grit and shale series. Grit	.5
10. Red shale	3.0
11. White grit	3.0
12. Red shale with greenish spots, ripple marks and rain prints (Specimen 11316)	14.0
13. Grit, mostly light colored	.75
14. Red shale	.25
15. Grit	2.0
16. Red shale	.25
17. Grit	.35
18. Red shale	.35
19. Grit	1.0

[1] Below this the numbering of the beds agrees with Winchell's section.

20. Red shale, mud cracks	3.5
21. Grit, white, quite calcareous from decomposition of basic feldspars	1.5
22. Red shale and shaley sandstone, with green layers and ripple marks	14.0
23. Light red sandstone	3.0
24. Red grit, some white	4.5
25. Shaley red sandstone, very hard; some white	10.0
26. Red grit	3.5
27. Dark red shale and shaley sandstone	9.0
28. Lighter colored sandstone (white and red)	8.0
29. Green shale, ripple marks	5.0
30. Red shale and shaley sandstone, ripple marks	9.0
31. Grit with shale layers	4.0
32. Red and white mottled cross-bedded sandstone	5.0
33. Grit and conglomerate, coarsest in middle	7.0
34. Shaley micaceous sandstone; pinches out	.75
35. Grit	.85
36. Red shale	.35
37. Grit	2.0
38. Red shale	.2
39. Greenish grit	.5
40. Red and white sandstone, pinches out into conglomerate. Under microscope (Specimen 11300) shows that *over three-quarters of the rock is quartz.* Remainder includes feldspars, mainly orthoclase, although both microcline and plagioclase were distinguished, mica, and rarely ferromagnesian minerals. Average size of the grains is about .25 mm. but there is much variation. All are subangular	1.2
41. Red grit passing below into coarse light colored sandstone; cross-bedded	3.5
42. Red conglomerate, coarser below; pebbles up to two inches	7.0
43. Red shale with green spots; some conglomerate	1.5
44. Firm light-colored conglomerate with enclosed layers of cross-bedded sandstone	3.0
45. Green and red shale, micaceous	.7
46. Sandy shale	1.0
47. Fine red shale, ripple marks	15.0
48. Quartz Conglomerate. Coarse hard pyritiferous conglomerate. Color usually white to greenish. In-	

PHOTOMICROGRAPHS IN ORDINARY LIGHT, MAGNIFIED 12 DIAMETERS.

A. Very fine-grained greenish calcareous shaley sandstone from Middle River, bed 1, Amnicon formation (specimen 8611). The light-colored grains are fine angular quartzes, averaging .01 mm. in diameter. An occasional feldspar is seen, and mica is visible in the hard specimen. The matrix of the rock is crystalline calcite, which in one place forms a vein in which its characteristic cleavage may be seen. A chemical analysis shows CaO 10.71%, MgO 0.12%, which would require 8.55% CO, making a total of about 19% of carbonate (see p. 32).



B. Fine-grained arkose sandstone from Amnicon formation, bed 7, St. Louis River (specimen 11.321). Quartz constitutes a little less than half of the rock. The remainder is feldspar (mainly orthoclase, but some more basic varieties), with iron oxide, a little mica, and calcite cement.

cludes layers of shaley sandstone, red conglomerate and red or green shale	50
49. Conglomerate, somewhat coarser and very hard. The pebbles are of vein quartz, slate, quartzite, and iron formation. But one trap pebble was found. A foot of green shale is found in places next to the underlying slate	100
Total thickness	727
Total thickness computed from dip and allowing for faults	730

Huronian

50. Thomson slates. Gray slate	Unknown

A number of wells in Superior[1] disclose a similar succession. The result of the southeasterly dip of the sandstones is that while in East Superior solid brownstone is found, along the St. Louis River to the west there is only discovered red sandy shale, carrying a little salt water. The deepest well of which the record was obtained, is Patterson's, in N. E. ¼ of N. E. ¼ of Sec. 24, T. 49, R. 14 W. (see general map). This penetrates 185 feet of dry drift, below which was found over 700 feet of red sandy shale, undoubtedly belonging to the Amnicon formation.

Summary. The exposures described above show that the stratigraphic sequence of a downward gradation through progressively more and more arkose sandstone into red shales, sometimes interbedded with conglomerate and grit, is found throughout the district. In the case of the exposures on Middle and St. Louis rivers it is practically certain that the upper beds belong to the Bayfield group. On the other hand, in the case of the Fish Creek section, farther east, the lower beds plainly belong in the Oronto group, and are seen to grade upward into sandstones which are correlated with the Bayfield group. These facts indicate that the Bayfield and Oronto groups are conformable and hence should both be placed in the Upper Keweenawan series.

[1] Records furnished by J. A. Colwell, a well-driller, 1900, and Prof. J. A. Merrill, 1910.

The only alternative is to suppose that the Bayfield group rests unconformably upon the Oronto group, somewhere beneath the drift-covered interval at the head of Chequamegon Bay. While this cannot be disproved, there is nevertheless no evidence of any kind to indicate that such is the case and on such an hypothesis must rest the burden of proof.

Categorically the evidence may be stated as follows:—

1. The same conformable downward gradation from more quartzose into more feldspathic sandstone and red shale is found at several widely separated localities within the district.

2. At most of these localities the indentification of the upper beds with the Bayfield group is indisputable.

3. On Fish Creek the correlation of the lower beds with the Oronto group is almost equally definite, thus indicating that the lower beds at other places are presumably the top of the Oronto group.

4. No debris worn from the rocks of the Oronto group has been found in rocks of the Bayfield group. For the most part the younger sandstones are made up of grains which average somewhat larger in size than those of the Oronto group, thus showing that the materials of the Bayfield group must in any event have been largely derived from other sources than those of the Oronto group.

5. There is no universal structural difference between the two groups. The Bayfield group lies in the center of the Lake Superior synclinorium and hence is usually nearly horizontal; but near Superior, all along the great fault of the Douglas trap range, and apparently on Fish Creek, it was involved in the extensive folding and faulting formerly supposed to be confined to the Oronto group.

6. If the Bayfield group is unconformable upon the Oronto group, then its lowermost exposed member is indistinguishable on lithologic or structural grounds from the recognized Oronto group.

There is, therefore, no reason to place the Bayfield and Oronto groups in different periods, and the evidence at hand drives us to the conclusion that the Bayfield group is a part of the Upper Keweenawan series.

A. North bank of St. Louis River, near line between St. Louis and Carlton counties, Minnesota. The cliff exposes red shale, with thin greenish sandstone partings. This is a part of the Amnicon formation. A normal fault of at least 40 feet displacement passes through the east end of the exposures (see p. 91).

B. West bank of Middle River, Sec. 25, T. 18, R. 12 W., Douglas County, showing contact between the Middle Keweenawan traps at left of ravine, and overturned beds of red and greenish feldspathic sandstone and shale of the Am-

CHAPTER VI

THE CONTACT OF THE BAYFIELD GROUP WITH THE TRAPS

General Statement. All along the south coast of the west end of Lake Superior the Bayfield group of sandstones comes into contact with the traps of Middle Keweenawan age, with dip to the southeast at angles varying from 10 to 70 degrees. At the head of the lake, on St. Louis River, near the western border of the state, the conformable downward extension of this group. the Amnicon formation, appears from beneath the younger sandstones and is plainly in unconformable contact with the underlying slates of Huronian age.

Douglas Fault. It has long been recognized that the contact of the Bayfield group with the traps of the Douglas (or South) Range is marked by a fault. With regard to the age, extent, and significance of this displacement there has been much diversity of opinion. As explained in Chapter III, Irving was of the opinion that the contact was an unconformity along a fault scarp complicated by slight recent movement on the same plane. Since that time, Grant recognized that an enormous displacement has taken place since the deposition of the sandstone, and that the fault is of the thrust type (see p. 89).

LOCAL DETAILS

On Iron River, near the eastern boundary of Bayfield County, is the most easterly known exposure of the traps of the South or Douglas Range. Several miles west of this small outcrop, the crest of the Douglas trap range rises above the plain

of Pleistocene deposits (see p. 7, and Plate II, p. 8). Where Brule River crosses through a deep gap in this ridge, the contact of the sandstone and trap is not exposed; it occurs beneath a covered space of about a fourth of a mile. No distinct evidence of faulting or other disturbance appears at this point in either formation. A contact showing fine conglomerate was reported by Sweet[1] (see p. 44), in Sec. 30, T. 48, R. 10 W. This locality was visited by Grant's party, but the exposure was not found.

Middle River Contact. Ten miles west of the Brule, Middle River exposes the contact of the traps and the Amnicon formation, which conformably underlies the Bayfield group (see p. 66). Berkey, Van Hise, and Grant visited this locality in 1899 and made the map which is the basis of Plate XIII. They recognized the true bedding of the sandstone, which Sweet had not,[2] and assumed that the structure was anticlinal. (See also Plate XVII, B, p. 74, and Plate XXI, p. 90).

The writer decided that this interpretation must be an error, since the stratigraphic sequence observed in other localities is exactly opposite to that required by such an hypothesis (see section on p. 67). No evidence could be detected of a small syncline next to the fault at the eastern exposure,[3] such as would be expected below a thrust fault. The fault cuts the E-W strike of the fold, the layers in which are somewhat broken near the contact. Furthermore, as explained on p. 68, ripple marks are found, which clearly demonstrate that the southward-dipping beds have been overturned. The structure deduced from these facts is that of an overturned and broken anticline, a normal structure in connection with a thrust fault; while that described by Grant would be unusual.

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[1] Sweet, E. T., Geol. of Wis., 1873–9, vol. III, p. 348.

Irving, R. D., Copper-Bearing Rocks, Mon. U. S. G. S., vol. V, 1883, p. 257.

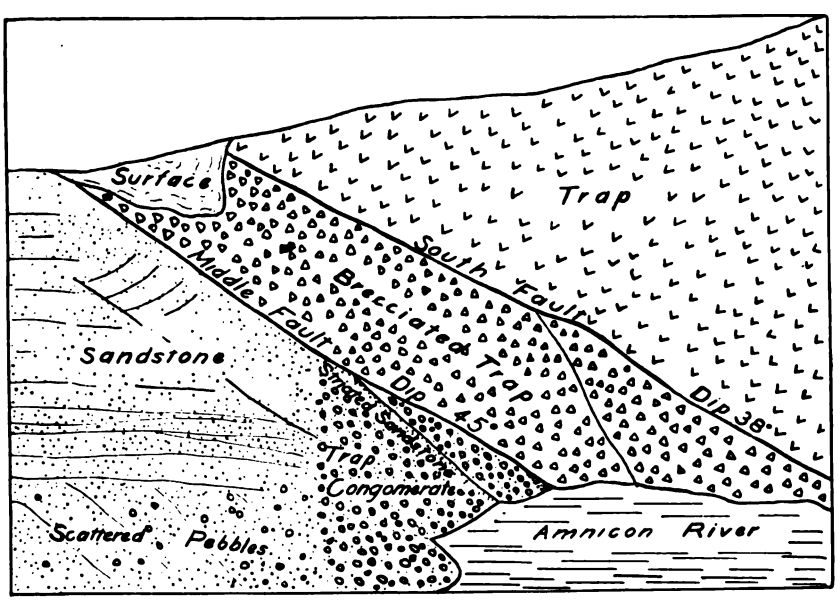
[2] Sweet, E. T., Geol. of Wis., 1873–9, vol. III, p. 347.

[3] Grant, U. S., Copper-Bearing Rocks of Douglas Co., Wis. Geol. & Nat. Hist. Survey, Bull. VI, 1901, structure section C–D on Plate IX, p. 31.

—— Junction of Lake Superior Sandstone and Keweenawan Traps in Wis., Bull. Geol. Soc. of America, vol. 13, 1906, p. 8.

Personal communications.

A. East bank of Amnicon River, Sec. 29, T. 48, R. 12 W., Douglas County, showing thrust fault, which brings the traps into contact with the Orienta sandstone.



B. Key to the foregoing photograph.

Amnicon River Contact. Where Amnicon River crosses the fault, occur good exposures which bring to light the actual plane of contact.[1] Changes in the course of the stream have resulted in uncovering the formations for a considerable distance, as shown in Fig. 10. These exposures are particularly interesting, in that they show the direction of the fault to change abruptly from nearly E. and W. to N. 70° E.

The eastern exposure, which doubtless was at one time a channel of the river, is in a deep and narrow ravine following the

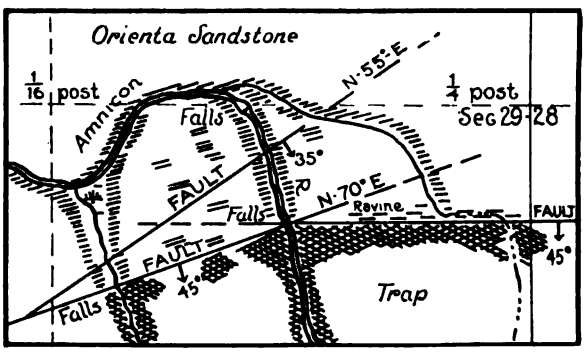


FIG. 10. Sketch map showing contact of trap and sandstone on Amnicon River, Douglas County.

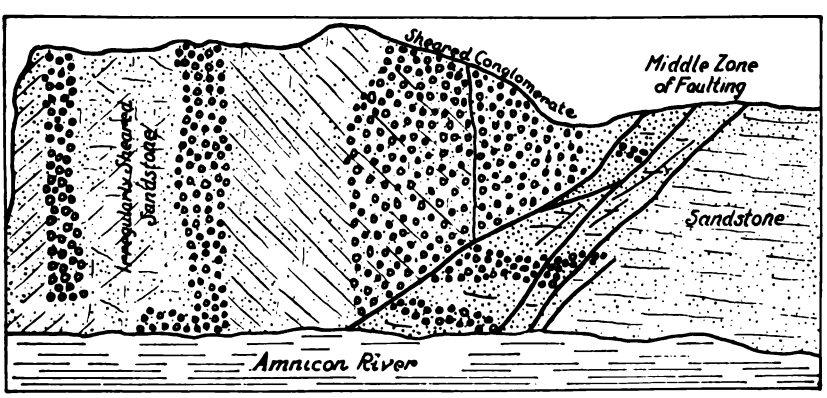
contact for some distance. The actual junction is covered with but a few inches of soil. The south side of the ravine is an overhanging wall of brecciated trap. In the bottom, occasionally rising into ridges, and on the north wall, occur exposures of conglomerate with interbedded layers of sandstone. The dip of the beds varies from vertical to about 45° N.; but the exact relation of the horizontal sandstone farther to the north could not be determined because of fallen debris and the irregular shearing that conceals the true bedding. It is probably marked by faulting, as will presently be explained. The conglomerate is composed of trap pebbles, usually much weathered, averaging an inch or two in diameter, but with occasional specimens a foot in diameter. All are well rounded, and, so far as was ascertained, composed mainly of porphyry and amygdaloids. The

[1] Sweet, E. T., Geol. of Wis., 1873–9, vol. III, p. 346.
Grant, U. S., Copper-Bearing Rocks, p. 19.

sandstone matrix and interbedded layers do not differ, except in coarseness of grain, from the rock exposed to the north (p. 43); some, however, appear to contain more small fragments of trap. At the west end of the ravine is exposed a thin layer of hard ferruginous sandstone. It forms the face of the north wall, dipping south at approximately the same angle as the fault (about 45°), thus cutting across the vertical layers of conglomerate and sandstone beneath. On the upper surface of this layer are two sets of grooves; one is parallel to the dip, the other is inclined at an angle of about 30° in a NE–SW direction.

The exposures are naturally much better on the present banks of the stream to the west (Plate XXII, B, p. 92). That this present course has not been occupied by the river for a great length of time, is shown by the fact that the fall of about 15 feet, just at the fault line, has receded but slightly into the traps. Plate XVIII shows the eastern wall of the gorge. Two faults are seen, of which the upper or southern one dips 38° S. with an E–W strike; the lower 46° S., strikes N. 72° E. They are separated by a zone of trap breccia, such as also occurs beneath much of the bottom of the ravine to the east, as above described. It consists of angular and subangular fragments of weathered trap, some of them several feet across. North of the lower fault occurs a wedge of conglomerate, bounded on the north by an approximately vertical plane. In this conglomerate are two thin sandstone layers striking parallel to this fault, and dipping south at a somewhat steeper angle than the fault. The southern one is almost quartzite, and the other carries scratches like those noted to the east. The bedding of the conglomerate is otherwise indistinguishable. In places to the north it appears to be vertical, as shown by an interbedded sandstone layer; but there, with no appearance of fracture, the conglomerate gives way above to horizontal thin-bedded quartz sandstone, and below to cross-bedded pebbly white sandstone, among the pebbles of which are some of quartz and quartzite. There an appearance of gradation is presented, but above the contact is sharp. Shearing makes the relations difficult to determine. Above the top of the conglomerate the foot wall of the fault is composed of much fractured sandstone. About 100 feet to the north a small thrust fault of undetermined throw is seen in the sandstone, as shown

A. Lower Falls, Amnicon River, Douglas County (see Fig. 10, for location). Looking north, showing Copper Creek beds of Orienta sandstone.



B. Diagram (drawn from a photograph) of part of west bank of Amnicon River, Douglas County, just north of contact of trap and sandstone (south of the falls shown in A)—for location, see Fig. 10. This exposure shows the dying out of the middle fault into a confused zone of fractures which separates the vertical conglomerate layers from the horizontal sandstone to the north—shown at the right. The shearing planes in the vertical layers are very complex, and are but partly represented.

in Plate XXII, A, p. 92; the dip is 38° S., the strike about N. 55° E.

The west bank is not so well exposed, owing to a recent fall of the overhanging wall of trap, thus concealing the main fault. Two other zones of displacement may be seen to the north. The southernmost of these is important since it shows the relation of the vertical sandstone and conglomerate to the horizontal sandstone beds.

It is not clear just how the middle fault is related to that described on the other side of the river. The two there seen, appear to join beneath the water, so that no well-defined breccia is seen on the west bank, the actual contact being marked only by an inch or so of red shale. The middle fault of the west bank branches out from the others beneath the river. It is composed of several irregular planes of fracture, as is shown in the plate Between the two faults is found conglomerate with irregular interbedded sandstone layers, all much sheared, as is imperfectly shown in Plate XVIII a, B, p. 78. A remarkable feature is the sudden ending of one of the conglomerate layers against sandstone below, with no appearance of fracture. Whether or not the alternation of conglomerate and sandstone represents bedding, is not known; but it is worthy of note that no conglomerate is found in undisturbed sandstone beds, while most of the layers occupy a vertical or highly tilted attitude and are much sheared. This intense shearing is quite irregular; no permanent system could be discovered, although many of the planes of fracture dip toward the fault at a low angle. In the western bank the northernmost fault is again seen, dipping to the south at an angle of 28°.

There are but poor exposures in the wide valley that crosses the fault to the west of the river. The inclined conglomerate beds reappear, but their relation to the horizontal beds to the north is not clear on account of the intense shearing; no pebbles extend beyond their limits. Fractures approximately parallel to the fault are most abundant, apparently representing the dying out of the middle fault. The strike of the contact is here N. 70° E. while that of the conglomerate is N. 50° E.[1]

[1] About a quarter of a mile to the west is a valley which crosses the contact and is believed to show exposures; the writer was, however, unable to visit it.

Copper Creek. In sec. 15, T. 47, R. 14 W., Copper Creek crosses the contact of the sandstones with the traps. The actual junction is covered by a few feet of debris, so that the attitude of the fault plane is difficult to determine.[1] Sweet's section shows it dipping to the north, but the writer was inclined to believe that the dip is about 60° to the south. The sandstone is sheared and sharply flexed for a distance of less than a hundred feet from the contact, thus indicating an upward movement of the igneous rocks. No conglomerates or other unusual features are found in the sandstone.

Falls of Black River. What is probably the best known exposure of the sandstone-trap contact is that in the S. E. ¼ sec. 21, T. 47, R. 14 W., at the picturesque falls of Black River. The locality is, however, more attractive for its scenery than for its rocks, for the latter are not everywhere well exposed.[2] Plate XIX is a map of this locality made by Grant in 1899, and shows the complex relations of the formations more clearly than could any description.

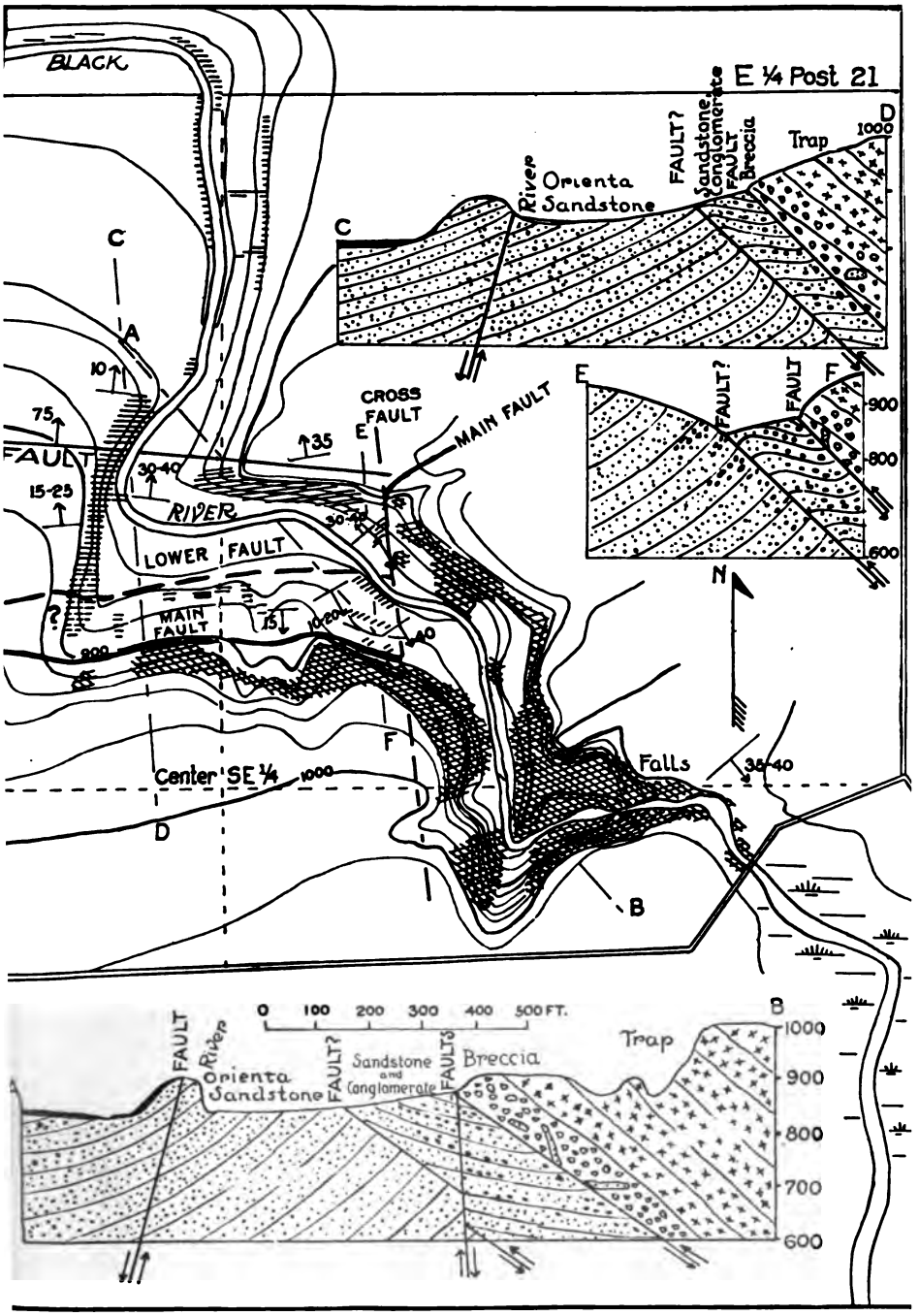
Conglomerate is found in but two places. The pebbles are decayed acid lavas, vein quartz, and red quartzite, preserving about the same proportions as the pebbles in the main body of the sandstone. The sizes, however, average somewhat larger, pebbles six inches in diameter being found.

On the east bank, not far above the stream and beneath trap layers higher up the bank, is a ledge of conglomerate with two interbedded sandstone layers which dip 30–40° N. This is quite close to the main fault (which here dips some 50° S.) and to the supposed cross fault. Above the conglomerate, sandstone, bearing but occasional pebbles, approaches close to the fault.

On the west bank of the stream is a larger ledge of conglomerate and sandstone. The dip here is reversed, being about 10 to 20 degrees to the southeast. This feature is shared, as may be seen in the diagram, by a number of sandstone exposures to the

[1] Sweet, E. T., Geol. of Wis., vol. III, 1873–9, p. 344.
Grant, U. S., Copper Bearing Rocks, p. 19.

[2] Sweet, E. T., Geol. of Wis., vol. III, 1873–9, p. 340.
Grant, U. S., Copper Bearing Rocks, p. 19.



Map of vicinity of Lower Falls of Black River, Douglas County, showing contact of Middle K
errawan traps and Orienta sandstone. Map by U. S. Grant, 1899; sections by F. T. Thwaite
910. Contour interval, 20 feet; elevations, 11 feet too high.

west. All of these rocks are quartzose, like those to the north, the only difference being that they are considerably harder.

Above these exposures rises a cliff of trap breccia, in which are included several large pieces of red quartzite. The extent of the brecciation is much greater than noted elsewhere, extending several hundred feet from the contact. The dip of the fault here cannot be measured, but appears to be not very steep.

The sandstone north of a line bounding these south-dipping exposures, as usual dips to the north. These beds are described on p. 44.

A study of the detailed map shows that the reentrant in the fault line must be the cause of the abnormal features here noted, just as the bend in the reverse direction at the Amnicon River is accompanied by peculiar phenomena. There must be a cross fault to account for this reëntrant angle in the border of the trap; the excessive brecciation is doubtless due to its presence. It is most probable that the south-dipping layers of sandstone are separated from the north-dipping by a continuation of the fault to the east of this break. This fault probably passes through the poor exposures on the west side of the valley, although they are so obscure that nothing can be stated positively; it may, however, join the main or southern fault beneath a covered space farther to the east. The writer could distinguish no definite evidence of unconformity, or of this reentrant being a sinuosity of an ancient shore line, as supposed by Irving.[1]

In the S. E. ¼ of the N. W. ¼ of sec. 29 of the same township occurs a small exposure of the contact. Irregularly-sheared sandstone occurs within two feet of trap breccia and dips about 40° N. for a short distance from the contact.

Interpretation of Exposures. Irving believed that the phenomena above described represented an unconformity along a fault scarp, complicated by a slight amount of recent faulting on the same plane. Grant discovered the great amount of throw (at least 3,000 feet; see p. 66) which the fault possesses, and declared the evidence to be not conclusive in favor of uncon-

[1] Irving, R. D., Copper-Bearing Rocks, Mon. U. S. G. S., vol. V, 1883, p. 441.

formity. All former investigators have assumed that the sandstone was a marine deposit, a fact now regarded as decidedly doubtful.

The following evidences favor the older view:

1. The presence of conglomerates, often of large pebbles mainly, if not sometimes wholly, derived from the rocks of the adjacent trap series.

2. The striking difference in the amount of folding and metamorphism of the two groups of rocks, which implies that most of the deformation of the traps must have taken place before the deposition of the younger sandstones.

3. The enormous throw and subsequent erosion required by the fault hypothesis.

4. No strata are known from which the conglomerates might have been faulted up; these is little to show definitely that they have been faulted up more than a few feet.

5. The dip of the fault plane to the south, giving it a large horizontal component of motion, would have cut away a large part of the coarse deposits adjacent to the fault scarp, thus explaining the absence of conglomerate at some points.

6. As the fault is part of the Keweenawan deformation, representing a broken fold, it is quite probable that faulting began before the time of deposition of the adjacent sandstone, and perhaps continued through the time of its formation.

7. The Bayfield sandstones may be areally continuous with the horizontal light-colored sandstones of the Mississippi valley (cf. p. 58), which are separated from the tilted Middle Keweenawan by a considerable unconformity.

The following facts support the idea that the faulting is in large part, if not wholly, later than the deposition of the sandstone:

1. Well defined conglomerates occur at but two localities out of the eight known exposures (less definite ones occur at two others).

2. They are never found over a few rods from the contact.

3. They do not clearly grade into the adjacent sandstone.

4. They occur only at points of unusual minor faulting in the sandstone.

5. No patches of sandstone are found resting uncomformably upon the trap.

6. The amount of conglomerate is not sufficient, nor are the pebbles large or angular enough, to be regarded as either a subaerial or marine deposit along a fault scarp.

7. In many cases the pebbles are one-third vein quartz and quartzite; these could only have been supplied from a distant source, and would not be likely to occur along a fault-scarp. The trap pebbles were not usually derived from the immediately adjacent rocks.

8. The inclination of the fault plane involves a large horizontal component, approximately equal to the vertical one. If faulting took place during or just prior to the deposition of the sandstone, this would involve a shifting northward of the scarp line, thus supplying a large amount of fresh unweathered sediment. No such amount of sediment of that character is found in the upper beds of the sandstone.

9. The throw of the fault since the deposition of the sandstone is certainly great; it must be at least 3,000 feet, since that thickness of strata is involved on Middle River.

10. The total displacement involved, even if the traps are as thick as was formerly supposed (see p. 89), is not greater than that of many well-known thrust faults. The uplifted rock may readily have been eroded during the long time that has since elapsed.

11. The conglomerates that occur are so intensely sheared that they may represent material from lower conglomerates which has been dragged up along the fault and worked into the sandstone, like the layers of sandstone that have been found included in the trap breccia (see p. 81). This hypothesis would explain some of the peculiar features of the conglomerates, found only at points of intense faulting. We have no knowledge of the stratigraphy of the lower beds of the sandstone in this part of the area, but conglomerates almost undoubtedly occur at lower horizons.

12. At several points, cross-bedded layers in the sandstone dip toward the fault. This would be an unusual occurrence if the rocks occupied the same relative positions at the time of the deposition of the sandstone, as they do today.

13. The areal connection of the Bayfield group with the Cambrian sandstones of Minnesota is not proved; the age and structural relations of the red sandstones beneath the light-colored Potsdam of Minnesota are unknown (cf. p. 58).

14. If the supposed fault scarp was being eroded during the deposition of the sandstones, then the sandstones must have been formed very soon after, if not during a period of regional deformation. This contrasts them sharply with those of the recognized Cambrian of southern Wisconsin, which were evidently formed under quiescent conditions (cf. p. 101).

15. The sandstones adjacent to the fault (Bayfield group) are apparently conformable upon those which overlie the traps (Oronto group) and elsewhere are folded with them. They all belong to the same period of deposition. Therefore it is very improbable that the exposures described above represent an unconformity involving any great lapse of time. If there is any unconformity, it is rather a local matter formed by slight movements of the fault during the deposition of the sandstones.

The writer concludes that inasmuch as deformation appears to have been more or less continuous throughout Keweenawan time, the probabilities are, that while most of the movement on the fault may have been accomplished before the deposition of the sandstones now exposed, that slight movements may have occurred during their deposition, while a considerable amount has demonstrably occurred since. This hypothesis agrees best with all that is known of the phenomena (cf. p. 108).

North Coast Contact. Near Duluth, several supposed contacts of the sandstone with the trap came to the notice of the writer. Upon investigation they proved to be either red syenite, cemented drift, or interbedded Middle Keweenawan sediments. But as explained on p. 107, it is entirely possible that an unconformable contact may yet be found.

St. Louis River Contact. Although on St. Louis River the Amnicon formation of the underlying Oronto group is seen in contact only with the Huronian slates, the presence of basic trap pebbles in such abundance implies a nearby exposure of Keweenawan igneous rocks during deposition, and hence a possible unconformity. Less than a mile from the exposures on Mission Creek, near Fond du Lac, hills of intrusive gabbro rise

to a level some 500 feet above the exposures. About the middle of the interval between these exposures, some real estate speculators at one time drilled a deep hole in search of natural gas, the log of which is here given:

LOG OF CHURN DRILL HOLE NEAR SHORT LINE PARK, MINN.

Situated on S. line Sec. 32, T. 49, R. 15 W., in a ravine at elevation 900 feet A. T. (After N. H. Winchell, Natural Gas in Minnesota, Minn. Geol. and Nat. Hist. Survey, Bull. V, 1889, p. 31; Geology of Minnesota, Vol. IV, 1899, p. 567.)

	Thickness, feet
Pleistocene.	
Drift (clay?) no samples	100
Keweenawan	
2. Rock, said to be soft, no samples	131
3. Brownish red shale (called tuff by Winchell)	12
4. "Decayed trap", perhaps conglomerate	33
5. No samples, presumably same as above	104
6. "Surface eruptives", perhaps conglomerate	37
7. The same, samples appeared to be in part fragmental, hence is probably a conglomerate	31
8. Gray slate or shale, said to be misplaced in record, but is possibly one of the greenish siliceous shales of the Amnicon formation	15
9. Pink to purple quartz sand with some trap fragments	5
10. The same but coarser and pyritiferous with pebbles of trap	5
11. "Gray slate", probably shale rather than slate misplaced in the record	17
12. "Gabbro"	16
13. Conglomerate of soft trap pebbles	2
14. Pink and gray quartzose, pyritiferous conglomerate and quartzite containing pebbles of slate, and probably layers of shale	20
15. "Surface lavas like those at Duluth." These rocks are clearly igneous	91
Huronian–Thomson Slate	
16. Gray and black quartzose slate	930½
Depth of hole	1,517½

A little salt water was found, but no gas.

The interpretation of the foregoing record is difficult. Winchell[1] correlated No. 14 with the similar white quartzose, pyritiferous conglomerate which is exposed on the banks of St. Louis River, to the west. He believed that the conglomerate seen in the river valley was older than the Keweenawan lava flows, since it contains no trap pebbles. (One large one was found by the writer, see p. 70). The red conglomerates and shales of the St. Louis River section, which at that point immediately overlie the pyritiferous conglomerate, he held to be either separated by an unconformity from the pyritiferous conglomerate or to have been deposited contemporaneously with the traps. The interbedding of traps and conglomerates, which he believed was shown in the above drill record, fits with either hypothesis.[2] A single pebble of pyritiferous conglomerate found by him in the red trap conglomerate, was believed to come from the underlying conglomerate and therefore to indicate an hiatus between the deposition of the two conglomerates, the upper one of which he believed to be of pyroclastic origin. This view is illustrated in Plate XX, A.

Winchell's views were not borne out by the writer's investigations. It seems clear that there is no unconformity between the two types of conglomerate on St. Louis River. The pebble of pyritiferous conglomerate found in the upper conglomerate, may well have been derived from some other similar formation. Furthermore, no evidence of contemporaneous volcanic eruptions was discovered in the Amnicon beds of St. Louis River and Mission Creek. These sediments do not differ essentially in character from the other parts of the Oronto group. It would therefore appear probable that the pyritiferous conglomerate found in the drill hole is not the same as that on the river, but is a part of the Middle Keweenawan trap series with which it is interbedded. The scarcity of coarse trap debris, especially of the gabbro, in the conglomerates of St. Louis River, suggests that faulting since the formation of the sediments has brought the traps into their present position, so that they rise 500 feet or more above the river level.

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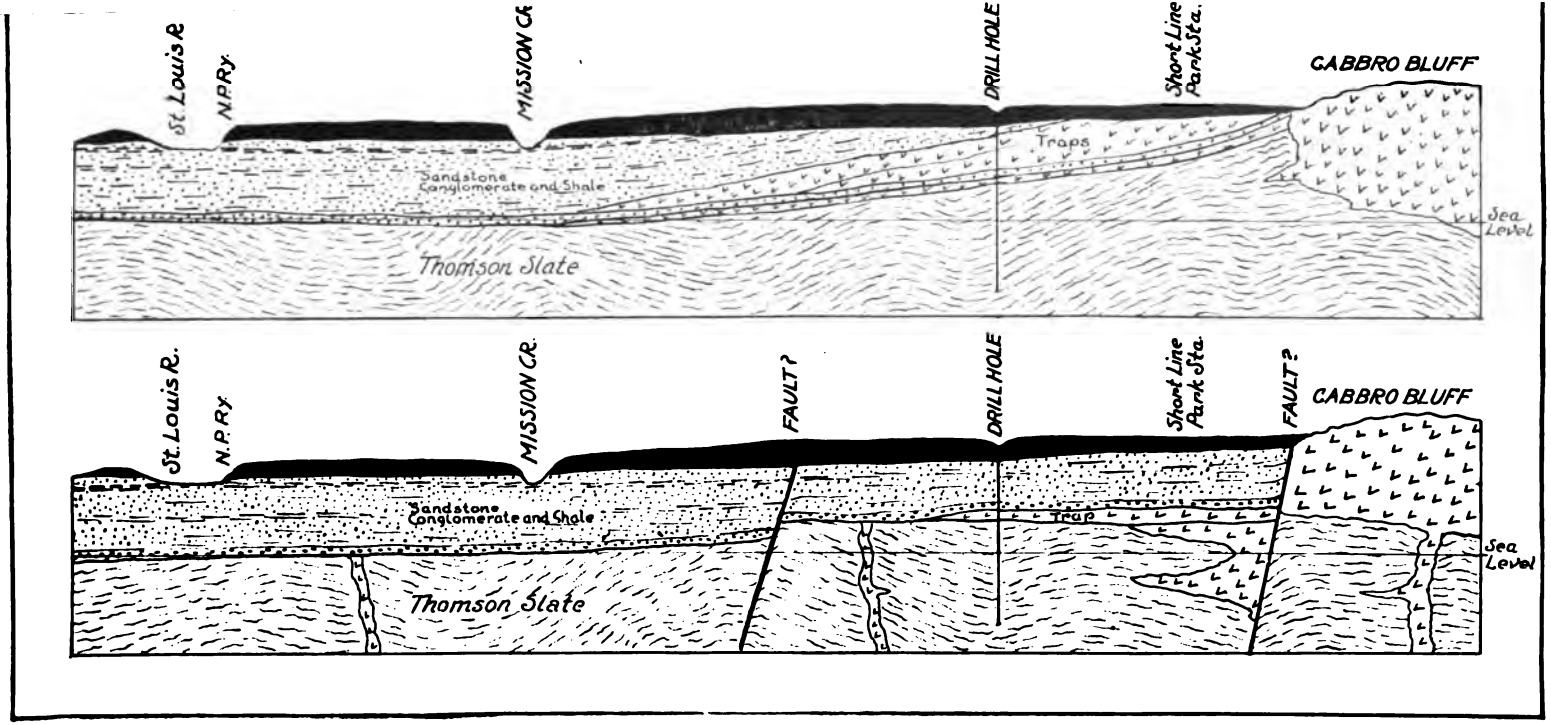
[1] Winchell, N. H., Geol. of Minn., vol. IV, 1899, p. 15.

[2] Hall, C. W., Keweenawan Area of E. Minn., Bull. Geol. Soc. of America, vol. 12, 1901, p. 342.



Upper section. Interpretation of geology, as given by Minnesota Geological Survey. The quartz conglomerate is shown interbedded with the traps, according to this interpretation of the drill record. The conglomerate was correlated with that shown at the left end of the section, just above the Thomson slate, thus indicating an interbedding of the Amnicon formation and the traps.

Lower section. A different interpretation of the geology. All of the material above the quartz conglomerate, is believed to be sedimentary, the drillings having been wrongly identified. The conglomerate found in the drill hole just above the trap, is still believed to be the same as that found just above the slates farther to the west. The Amnicon formation overlaps the edge of the traps, and may either be unconformable against the gabbro bluff or have been faulted against it, as shown in the section.

Still another explanation of the ambiguous record of the Short Line Park drill hole is, that all the strata above No. 15 are sediments, the drillings from coarse conglomerates having been mistaken for traps by Winchell. The large amount of fragmental material noted in his descriptions of the drillings, supports this view. Moreover, a resident of the vicinity who watched the drilling informed the writer that a daily progress of 10 to 12 feet, presumably in a single shift, was maintained with the use of 1,500-pound tools. Such a rate would favor the view that little or no solid trap was penetrated. If this view (see Plate XX, B) is correct, there may not be any fault between the drill hole and the gabbro bluffs, the conglomerates having been deposited at the base of the trap hills. The scarcity of gabbro pebbles in the drill hole, however, strongly indicates that a fault occurs between the drill hole and the bluff. Such an hypothesis best explains the present relation of the gabbro in the bluffs to the north, and the sediments found in the drilling.

Contact with the Slates. The contact of the Amnicon formation with the Thomson slate, on St. Louis River, demonstrates a progressive overlap. As shown in section A–B, on the general map, the traps must thin out and be overlapped in the space between the Douglas Range and this point. The same phenomenon must also occur in the short distance between Mission Creek and the Short Line Park bluffs (see p. 84).

As noted in the last chapter (p. 72), we find between the trap conglomerates on St. Louis River and the underlying slate a pyritiferous quartz and slate pebble conglomerate, which is clearly part of the Amnicon formation. The surface of the slate is rough, several small knobs showing through the conglomerate (see Plate XV, p. 70).

CHAPTER VII

THE STRUCTURE OF THE WISCONSIN COAST OF LAKE SUPERIOR

General Statement. The basin of Lake Superior is a broad and flat synclinorium. Toward the west end of the lake, this structural trough turns inland up Chequamegon Bay, and thence crosses Wisconsin in a great curve to the St. Croix valley[1] and into Minnesota (see p. 60). The southward-dipping Douglas or South Trap range divides it from the far western end of the lake, which is bounded on the north by the south-dipping traps of the Minnesota or North range.

The Bayfield and Oronto sandstone groups occupy the narrow strip between the north escarpment of the faulted Douglas Range and the lake, lapping across the course of the traps in the promontory of the Bayfield Peninsula and the Apostle Islands, and extending into the basin of the main syncline to the east. On the south shore the sandstones have a low southeasterly dip, a continuation of the inclination of the traps of the north coast, passing to the southeast into a series of broad open folds which occupy the bottom of the synclinorium. The major structural features of the region are the Douglas Fault, the North Coast

[1] Irving, R. D., Geol. of Wis., 1873-9, vol. III, p. 1.

—— Copper-Bearing Rocks, U. S. G. S. Mon. V, p. 410, with structure map and natural scale sections.

Hall, C. W., Keweenawan Area of E. Minn., Bull. Geol. Soc. of America, vol. 12, 1901, p. 313.

Grout, F. F., Contribution to the Petrology of the Keweenawan. Jour. Geol., vol. XVIII, 1910, p. 633.

Fault, and the folds within the Lake Superior synclinorium south of Ashland.

Douglas Fault. The exposures of the great fault along the northern edge of the Douglas or South Range have been described in detail in the last chapter—the conclusion being there reached that the displacement is in large part later than the deposition of the sandstones, although movement may have taken place before or during their formation. The fault plane dips to the south at angles varying from 38° to about 60°, and the south side is raised relatively to the north side, this fact showing it to be a thrust fault. Its origin is a broken anticline, as shown by the overturned fold of sandstone thrown up at one locality, and apparently it is allied in point of age with the period of Keweenawan folding. The displacement on this fault must be enormous, over three thousand feet being known at one locality. This can only be a fraction of the total, which must be equivalent to the sum of the thickness of the traps above the horizon at which the fault occurs and of the sandstones. The former rocks were estimated by Sweet[1] to be at least 36,000 feet thick, above the lowest horizon faulted up, provided that unknown faults have not duplicated the exposures. It seems probable that from 4,000 to possibly 15,000 feet of sediments overlie the traps (see structure sections on general map) in the vicinity of Superior. Since the displacement along the fault plane is greater than the stratigraphic thickness between the horizons on each side of the fault, a throw of from six to twelve miles is estimated. This figure is truly enormous, but is no greater than the absolutely proven displacements of many thrust faults. The shortening represented by the folds between Madeline Island and the Penokee Range is computed from structure sections E–F and J–K to be at least five miles, agreeing closely with the lower estimate given for the fault.

In its course (see general map in pocket), the fault does not exactly follow the northeast strike of the traps and sandstones, but turns in a zigzag line in a general E–NE direction, thus cutting across the strike of both series. Following it to the southwest, the fault thus progressively brings older sandstones in contact with younger traps.

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1 Sweet, E. T., Geol. of Wis., 1873–9, vol. III, p. 338.

The Douglas fault does not pass through the Apostle Islands, but appears to die out into a fold which in turn becomes gentler and finally flattens out beneath the drift-covered area of the Bayfield ridge. The dying out of the fault is to be correlated with the northeastward pitch of the minor folds (see p. 92), and the general broadening of the synclinorium in northern Ashland County. The compressive stress which to the west was relieved by the thrust fault, was there relieved by folding. It is very probable that this dying out is accompanied by normal faulting perpendicular to the strike. Such dip faults are known to occur at some of the angles in the course of the thrust fault (see p. 81). As indicated by the topography, the fault appears to follow a nearly straight line from where the trap outcrops on Iron River, to the southwest, where the Trap Range becomes ill defined; and finally, in the vicinity of Maple, in Douglas County, is entirely buried beneath the Pleistocene deposits. Where exposed on Middle River, the fault has a strike of N. 65° W., thus showing that there is a reentrant in its course beneath this unexposed gap. In this reentrant is found the great overturned fold of Middle River (see p. 66). This fold is apparently a local feature associated with the change in direction, but unfortunately the exposures on Poplar River are not sufficient to allow its eastern extension to be examined. Cross faulting may also occur.

Plate XIII, p. 66, represents the structure of the rocks exposed on Middle River, to the north of the fault; its general features have already been explained. Jointing in the sandstone is best developed along nearly horizontal planes (Plate XXI opposite). In some cases these show faulting, the upper blocks having moved a few inches to the north. The actual junction with the trap is not exposed, but is associated with no marked breaking or crushing of the sandstone. The trap is, however, considerably brecciated. The thickness of strata of sandstone involved in the fold shows that there has been at least 3,000 feet of movement on the fault at this point.

Between Middle and Amnicon Rivers, the fault takes a course nearly due west. Just at the crossing of the latter stream it resumes a southwesterly direction. This exposure is described in detail on pp. 77–79. It would appear that the confused fault-

MIDDLE RIVER, DOUGLAS COUNTY.

A. Vertical beds of red feldspathic sandstone of Orienta formation, showing horizontal joints formerly mistaken for bedding. Just north of bridge on south line of Sec. 24, T. 48, R. 12 W.

B. Overturned beds just south of the bridge, from which A was taken.

ing along planes essentially parallel to the main displacement, is due to this change in direction. Because of this, the striations seen on the sandstone (see p. 78) have little weight in disclosing the history of the displacement.

Southwest of Amnicon River, the fault follows the more or less marked escarpment of the trap range, to where it crosses Black River. The only good exposure of this portion, on Copper Creek, shows that the plane of movement dips about 60° to the southeast. The sandstone is sharply flexed and sheared for less than 50 feet from the junction.

Another reentrant occurs at the falls of Black River (Plate XIX, p. 80). This is marked by normal dip-faulting, as well as by faulting in the sandstone, parallel to the main plane of displacement, which is seen to dip about 50° to the south. The trap is intensely brecciated. A small normal fault of E–W strike is found in the sandstone still farther to the north.

West of Black River, only slight bends interrupt the southwesterly course of the fault. The only known exposure in Wisconsin (see p. 81) shows a sharp flexure of the sandstone and considerable brecciation of both formations.

In Minnesota, Hall[1] has shown that the great fault extends far to the southwest, nearly to St. Paul, but its age has not been satisfactorily determined.

North Coast Fault. For various reasons, the evidence being mainly physiographic, it has long been thought that the abrupt descent from the nearly level uplands of Minnesota to the deepest part of Lake Superior was marked by a fault.[2] Moreover, at Superior, deep wells show a considerable thickness of shale, across the river from the high trap hills. The dip of the formations here is not known, however, so that it might readily be steep enough to carry the sediments over the traps.

St. Louis River. On St. Louis River there is observable a dip of 6° to 10° to the southeast, together with a complex system of normal faults (see Plate XV, p. 70). These faults are un-

[1] Hall, C. W., Keweenawan of Eastern Minnesota, Bull. Geol. Soc. of America, vol. 12, 1901, p. 313.

[2] Martin, L., The Geology of the Lake Superior Region, Mon. U. S. Geol. Survey, vol. LII, p. 112.

usually well exposed (see Plate XXIII, B, p. 94), so that the exact plane of movement can usually be observed. This varies in dip from vertical to about 60° toward the downthrow side. This displacement varies from a few inches up to about 40 feet; the fault shown in Plate XXIII, B, has a throw of about 14 feet. The strike of most of the faults averages about N. 35° W., but a few have a nearly E–W direction. Occasionally, slickensides occur; these indicate more or less of a horizontal component to the motion. As already mentioned (p. 87), it appears necessary to assume the existence of a fault between the sandstones of Mission Creek and the trap bluffs at Short Line Park; but the drill record (see p. 85) near the latter locality is so ambiguous as to afford small help in locating the displacement.

Folds Near Ashland. Beneath the eastern plain southeast of Ashland, occur the most interesting structural features of the district. Unfortunately, however, few outcrops exist, so that much of the structure remains obscure. But sufficient evidence has been discovered to show that we have to deal with the south half of an asymetric synclinorium, in which the southward dips are comparatively gentle while the northerly dips are steep. The southern side of the synclinorium carries more minor folds than the northern (see structure sections on large map). These minor folds appear to pitch to the east and northeast.

The strata of the Apostle Islands represent the gently-dipping north limb of the great depression, while the faulted anticline of the Douglas trap range is a subordinate eastward-pitching fold on this limb. If the map were continued farther south, we should find (see Atlas Plate XXII, Geology of Wisconsin, 1873-79) that as the axis of this great Lake Superior synclinorium passes inland near Chequamegon Bay, it suffers a rather sudden bend from its northeast-southwest direction to a course slightly north of west. Farther to the west, however, as shown on the map by the line indicating the probable course of the synclinal axis, it resumes its usual southwesterly direction.

In the vicinity of Oronto Bay are good exposures of the southern limb of the main fold. Here the strike averages N. 53° E. with a northwesterly dip of 45° to 90°, the average being about 65°. Minor undulations are not common, nor are joints especially numerous (see table on p. 96). Small dip faults

A. Minor thrust fault of unknown displacement, in Orienta sandstone just north of main fault on east bank of Amnicon River, Sec. 29, T. 48, R. 12 W., Douglas County. This is the most northerly plane of faulting (see p. 77, and Fig. 10).

B. General view, looking south, of falls of Amnicon River, at contact of traps and Orienta sandstone. The falls are just on the fault (see Plate XVIII, p. 76, and Plate XVIIIa, p. 78).

occur in places, with striae showing that the movement has been mainly horizontal; the displacements are apparently not over 45 feet. Slickensides also occur on some of the beds, while inclined fractures dipping toward the northwest combine to give an impression that there has been strike faulting with the down-throw towards the lake. Inclined fractures striking parallel to the dip also occur, but the details were not worked out.

Northwest of Oronto Bay, the first minor fold of the synclinorium has its crest at the apex of Clinton Point. This locality is figured in detail in Plate IX, p. 54. The beds which dip to the southeast are submerged, hence are only visible when the water is clear and calm, and then are seen at their best from the top of the bank. Most of the exposures to the west are almost aswash, so that it is not surprising that former visitors have misinterpreted the structure (see p. 15). The inland continuation of the fold is unknown, the deep well at Birch not having struck rock at a depth of 300 feet; but apparently the anticline merges into the south limb of the main fold, as shown on the map.

Close to the north side of the anticline, runs the axis of a syncline, which must lie between it and the southeasterly-dipping rocks on Bad and White rivers. At the former locality the dip varies from 27° to 55° to the southeast with a strike of about N. 50° E; at the other, the strike is about the same, with a dip averaging about 25°. The rocks have not been greatly affected by the folding. Joints are not abundant, and most of them follow the strike (see table).

Passing again to the northwest, the next known exposures are those on the South Fork of Fish Creek, near Ashland. Here the strike averages N. 85° W., corresponding to that of the rocks of the south limb of the synclinorium farther to the south, while the dip is northerly at angles varying from 70° to 90°, the inclination lessening towards the north (see Plates VIII, p. 52, XI a, p. 62, XI b, p. 64, XI c, p. 64). There is no repetition of beds by close folding. Horizontal or slightly inclined joints are most common. On some of these there has been differential movement, so that the upper side has moved north. The maximum displacement noted was about four feet. A small thrust fault, dipping 20° S., was observed, but there was no evi-

dence of a displacement of more than 15 to 20 feet (see Plate XI c, A, p. 62). The strike of the fault is the same as that of the beds.

Between the north-dipping rocks of Fish Creek and the exposures on White River, five miles to the southeast, there must exist an anticline which may possibly be faulted like that of the Douglas Range. It is difficult to decide on which side of the center of the synclinorium this axis lies; but the evidence appears to favor the view shown on the map—that it is on the southern side, merging with the main south limb near the bend to the southwest. On account of the absolute lack of exposures west and northwest of Fish Creek, the distribution of the formations shown on the map is mainly hypothetical.

Structure of the Bayfield Group. The strata of the Bayfield group are in general but slightly inclined. The dip varies from nothing up to a maximum of about 5 degrees, except where the strata have been affected by the Douglas fault, and towards the edges of the synclinorium, on Fish Creek and St. Louis River, where greater dips are found. In spite of the fact that this dip is higher than the average for the flat-lying rocks in southern Wisconsin, joints are not as abundant as in the latter region. In most cases the fractures are irregular and often end at bedding planes (see Plate IV, B, p. 30). For the most part, only well-defined fractures were measured by the writer, since the minor ones are often curved or run in such a variety of directions that measurements are meaningless.

The accompanying table and diagram show that the best developed joints approximate an E–W direction; next in importance follow those which strike a little east of north, while northwest and northeast joints are occasionally noted. It will be seen that there is little relation to the direction of the strike and dip of the bedding, or to the main lineaments of the country. Many of the E–W joints are inclined, usually at a steep angle to the north.

Occasionally, beds are found that are much more fractured than those above or below. An instance of this is found near the northeast corner of Oak Island, where a shaley bed a few feet in thickness is cut into small slabs and sometimes long slivers, by a set of N–S and E–W joints. On Point Detour, Poplar

A. Sea caves in Devils Island sandstone, near Squaw Bay, Bayfield County (see p. 39).

B. Normal fault of 14 feet displacement, in arkose grits and sandstones of Amnicon formation. Gully just above railway bridge, Sec. 1, T. 48, R. 16 W., Carlton County, Minn.

River, and North Twin Island occur other sheared layers of sandstone. The fragments are usually subangular and consist of the adjacent sandstone, but they are always much weathered. They much resemble conglomerate on the weathered surface, but lack a decisively sedimentary character; while the layers often pinch out or run into irregularly broken rock. Presumably these phenomena are due to shearing and in part to concretions of iron (cf. p. 31).

Age of the Deformation. There is no direct means of determining the age of the deformation of the sandstone groups. It will be pointed out, however (see p. 101, in the consideration of their origin, that it is quite probable that earth movements went on simultaneously with the deposition of sediments of the Oronto group. It is also probable that the movements which formed the Douglas fault, continued throughout the period of deposition of the Bayfield group, for there has been a great amount of displacement since its beds were hardened. The Orienta sandstone, a member of the Bayfield group, is involved in the general regional folding in the vicinity of Ashland. In many places it would appear from the lack of secondary structures due to folding (see p. 92), that the deformation took place before the rocks were entirely indurated. This supposition agrees with the scarcity of joints throughout most of the area. Many faults, although formed after hardening, are now entirely recemented, while secondary fractures unrelated to folding are quite common. There is, however, no evidence of any marked deformation since that which produced the folds and faults. This deformation appears to have continued throughout all of the Keweenawan period.

Origin of West End of Lake Superior. The main body of Lake Superior occupies a great structural as well as topographic depression. It would appear probable that the deformation of the rocks took place mainly during and shortly after the Keweenawan period, and that the present depth of the topographic basin, slight compared with its width, is due to subsequent erosion (by what agency is unimportant for this discussion) of the relatively soft Upper Keweenawan sediments that occupied its center. Turning to the western portion of the lake, especially westward of the Apostle Islands, there is found little evidence

TABLE SHOWING DIRECTION OF JOINTS AND FAULTS—WEST END OF LAKE SUPERIOR

	Locality	Strata			Joints			Faults			
		E. of N.	W. of N.	Dip	E. of N.	W. of N.	Dip	E. of N.	W. of N.	Dip	Displacement
BAYFIELD GROUP	Washburn			S-5-1°	85°	0, 82°	90°				
	Houghton			S-5-?	0, 45, 90	45, 83	"				
	Pikes Quarry			S-5-?	0, 18 25, 81, 90	79-82	"		75°	90°	?
	Big Bay			?		60, 75	"				
	Basswood Id.				0, 90						
	Stockton Id.				0, 5-10, 90						
	Hermit Id.				0, 10-15, 90						
	Oak Id.	45°		SE 1°-5°	13 22, 45, 70, 80 84	65-70, 85-89					
	Devils Id.	45		SE-1-3		90					
	Sand Id.	45		SE-1-5	80-82	12					
	Eagle Id	45		SE-5	50						
	Siskowit R	45		SE-?	74						
	Port Wing	45?		SE ?	0	10, 55					
	Brule R	45		S-SE-2-3	0, 5, 30, 87						
	Poplar R.			S-0-6	65, 75-80						
	Amnicon R.	45 83		SE-E-1-10	38	5, 34					
	Copper Cr.				45	75					
	Black R.	55		SE 5	75						
GROUP	Oronto Bay	45-53		NW-50-75	33, 45, 60, 90	20 35, 40-45, 60			20 35, 40	90	5ft-45ft
	Clinton Pt	38-48		NW-12-40	35, 50	30, 50, 65	50 W. dip. NE				
					60, 75	15, 45, 80	crest anticline				
	Bad R.	45-55		SE-27-55	2, 38, 50		38 dips 60° NW				
	White R.	50-65		SE-25-28	50						
	Fish Cr.		78-88	N-70-90			Horizontal		85	820	Thrust
	St. Louis R.	50-60		SE-5-10	0, 10, 15-18, 32-35 53-67, 70-85, 90	10-25, 58, 78-87		85-90	30-10, 87	62-90	1ft-40ft

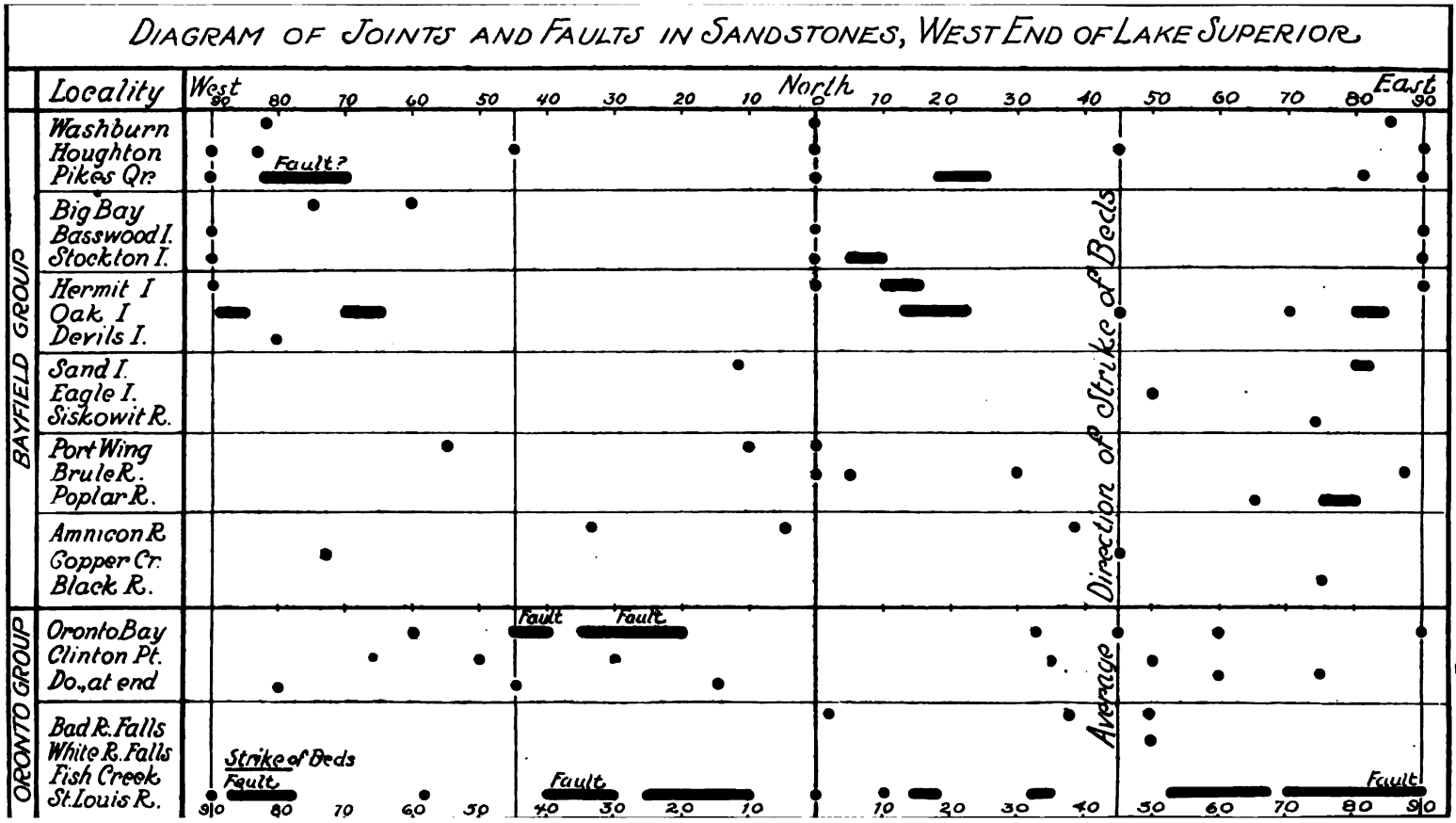
DIAGRAM OF JOINTS AND FAULTS IN SANDSTONES, WEST END OF LAKE SUPERIOR
Locality
West
North
East
BAYFIELD GROUP
ORONTO GROUP
Washburn
Houghton
Pikes Qr.
Big Bay
Basswood I.
Stockton I.
Hermit I
Oak I
Devils I.
Sand I.
Eagle I.
Siskowit R.
Port Wing
Brule R.
Poplar R.
Amnicon R.
Copper Cr.
Black R.
Oronto Bay
Clinton Pt.
Do., at end
Bad R. Falls
White R. Falls
Fish Creek
St. Louis R.
Fault?
Fault
Fault
Fault
Fault
Fault
Strike of Beds
Direction of Strike of Beds
Average

of a structural origin of the present topography, although the rock fractures of the Oronto Bay region do indicate a depression of the lake bed since the completion of the folding. Indeed, the lake does not extend so far up the main syncline south of the Bayfield Peninsula as it does north of the Douglas Range toward Superior. On the south side of this great western extension of the lake, we find no vestige of a structural origin, for the sandstone universally dips away from the lake.[1] (See structure sections on general map, in pocket.)

The explanation must lie in differential erosion. We can clearly discern that the Bayfield Peninsula must owe its origin primarily to different causes than the trap ridge of Keweenaw Point, which it resembles in outline. It may be supposed that the influence of the soft shales of the Amnicon formation is responsible for the development of the Superior-Duluth arm of Lake Superior. A study of the depth of the water shows that the deeper part, which is not over 900 feet, is confined to the neighborhood of the north coast, where this formation is believed to outcrop (see p. 73). At Superior, well records show that this ancient valley lies upon the shales next to the foot of the Minnesota trap range. It is known to have been eroded at this point to a depth of over 500 feet below the present lake level. In the case of the Chequamegon Bay region, the structure was more complex, so that beds of varying hardness and attitude were exposed by erosion. Buried valleys, almost as deep as those at Superior, are known from the records of wells south of Mason and in Ashland County.[2]

The Bayfield Peninsula, then, is a ridge of flat-lying, comparatively resistant sandstone, left as an erosion remnant between two areas mainly composed of shales and soft arkose. The outline of the islands is approximately that of the pre-glacial hills into which this ridge was cut. Some of the ancient valleys between them (as east of Outer Island) appear to have escaped filling by the glaciers which deposited the huge interlo-

[1] Owen correctly observed this feature. Geol. Survey of Wis., etc., p. 270.

[2] These records and many others are on file in the office of this Survey.

bate moraine upon this dividing ridge, thus giving to it its present height. That the erosion of this part of the Lake Superior basin was the work of streams, rather than of ice, therefore appears most probable.

CHAPTER VIII

CONCLUSIONS

General Statement. No fossils have been, or seem likely to be, discovered in either the Bayfield or Oronto groups of sediments, by means of which they may be assigned to a definite geologic period. They must therefore be correlated on the basis of lithologic characters, origin, and general stratigraphic and physiographic relations.

Summary of Lithologic Characters. The sandstones and shales of the Wisconsin coast of Lake Superior comprise an enormous thickness of sediments, amounting possibly to nearly 25,000 feet. In composition they show a progressive change, with but minor alternations, from sediments composed of poorly assorted and almost unaltered fragments of igneous rocks, to dominantly siliceous sandstone, which represents a marked degree of weathering and assortment of the original material.

The greater part of the lower, or Oronto group, may be placed in the first class. It is composed of debris of igneous rocks which usually was but poorly assorted, and little weathered or worn before deposition. In the Bayfield group, the forces of decomposition and sorting had greater effect, so that a much greater proportion of more resistant minerals are found. The dominant source of the sediments, moreover, had changed. The material of the older group was mainly, although not wholly, derived from the Middle Keweenawan traps, while the siliceous sands and orthoclase feldspars of the Bayfield group represent the debris of older sediments, granites, gneisses, and schists. Both groups differ from the older sedimentary series of the

Lake Superior region in containing, so far as known, neither iron formation nor distinct pyroclastic material.

Comparison with Sandstones of Southern Wisconsin. The differences of the rocks of the Oronto group from the sandstones of southern Wisconsin are clearly apparent. The Bayfield group, although in some horizons much like the southern rocks, differs in many important respects. Its color is usually some shade of red; while the southern sandstones, where they contain iron, are prevailingly yellowish. The dominant cement of the latter rocks is calcium carbonate, and this is almost entirely absent in the Bayfield group, its place being taken by silica and iron oxide. The sand grains are almost universally much less rounded, and the secondary enlargements are very irregular. Nevertheless they are more indurated. Much more feldspar, mica, magnetite, and other minerals derived from rather basic rocks are found. Clay pockets, and pebbly bedding planes, as well as irregular and curved bedding, are characteristic of the northern sandstones. But little clay shale, or clean quartz sandstone, and no fossils, occur in these rocks. All these facts point to different conditions of origin, as well as a somewhat different source of material, from that of the sandstones of the southern part of the state.

Origin of the Sandstones. The facts bearing on the conditions of origin of the Oronto group are numerous and almost indisputable. That it is a non-marine deposit is disclosed by mud-cracks, abundant ripple marks (often of the type produced by currents), rain prints, angular sand grains, poor assortment, absence of fossils, and by channels in shale beds filled with sandstone. All of these are features characteristic of stream deposits, laid down by shifting and variable currents of water, probably, but not necessarily, under desert conditions. The flat clay pockets are believed to be associated with the mud-cracks, being dried films of clay broken up and then buried in the sands. Another feature of fluviatile deposition is the abundant and irregular cross-bedding, dipping in various directions. The exact origin of the light-colored spots, so conspicuous in many localities, is unknown; until this is determined by chemical work, little can be concluded from the color of the rocks. They may be due to particles of either organic matter or iron pyrite. The

prevailing red color is generally believed to represent aridity at the time of deposition. Taken in connection with the absence of fossils, it certainly does denote a scarcity of life, the remains of which would have bleached the ferric oxide; but as iron was so abundant in the traps from whose debris the sediments were built up, this conclusion is rendered doubtful. Apparently, conditions were favorable to the oxidation, but not to the chemical concentration of iron, the magnetite beds being the result of purely mechanical processes. Likewise conditions were unfavorable for the chemical concentration of copper derived from the traps. The salty water often found in the rocks of the Oronto group is without significance, since both marine and non-marine sediments are salty.

Passing to the overlying Bayfield group, we again find nearly all of the features of terrestrial deposits mentioned above. Naturally mud cracks are not as common as in the more shaley rocks of the older group, but are occasionally found at almost all horizons. The flat clay pockets and eroded channels are abundant, but the latter differ in being often cut in sandstone and filled with shaley rock. Rain prints were not noted. No distinct evidences of wind action were discovered, although it is possible that some of the peculiar cross-bedding may be of dune origin. The angular character of the sand grains, however, does not favor such an hypothesis. Neither can any definite conclusion be drawn from the ferric oxide which gives the predominant color. It has been so thoroughly redistributed by the action of ground water that its original state is a matter of doubt. All that can be said is, that most probably it was originally confined to the finer grained beds. The irregularly scattered pebbles — concentrated only on bedding planes, and never forming beds of any thickness—are also believed to favor the hypothesis of fluviatile origin. No deposits like those at the foot of sea cliffs are found along the Douglas fault, although movement probably took place during the deposition of the sandstone.

Age of the Bayfield Group. The age of the Bayfield group cannot be definitely stated, as it could were fossils present. It must be correlated by the same methods that are used with the other non-fossiliferous series of the Lake Superior region. In

the past it has been considered to be of Cambrian age: first, because of the supposed striking difference in degree of folding from the recognized Upper Keweenawan sediments (Oronto group); and second, because of its likeness to the eastern Lake Superior (Jacobsville) sandstone of Michigan, which is believed to be Cambrian. In later years the probable areal connection of the Bayfield group with the red clastic series of southeastern Minnesota has been appealed to in order to prove the Cambrian age of the entire Keweenawan series. The possibilities are, then:

1. The Bayfield group may be unconformable upon the Oronto group, and be conformable with the Potsdam of the Mississippi valley. It may be either the same thing as the southern sandstone, or its conformable downward extension.

2. The Bayfield group may be unconformable upon the Oronto group, and be unconformable below the recognized Cambrian. It would then belong to an unknown and unrecognized period.

3. The Bayfield group may be conformable upon the Oronto group, and conformable with the known Cambrian. This would involve the assumption that the period of Keweenawan deformation and terrestrial deposition continued until the advancing Cambrian sea reached the Lake Superior basin, so that the two types of deposition merged into one another.

4. The Bayfield group may be conformable upon the Oronto group, and unconformable below the Cambrian. The time relations to the Cambrian could not then be ascertained.

The writer has sought to demonstrate in the foregoing chapters that there is no reason to believe in the existence of an unconformity between the Oronto and Bayfield groups. Both are a part of the Upper Keweenawan, none of the sedimentary rocks of which display much more metamorphism than do the Paleozoics to the south. The Bayfield group has moreover been shown to be horizontal, merely on account of its position in the center of the Lake Superior synclinorium. Locally it is involved in the more pronounced Keweenawan folds and faults, thus contrasting sharply with the relatively undisturbed Cambrian rocks of southern Wisconsin.

It seems highly probable that the red clastic series which fills the continuation of the Lake Superior syncline beneath the Paleozoic rocks of Minnesota, is the equivalent of part or all of the Upper Keweenawan rocks of Lake Superior; although they may now possess no areal connection with them, either by way of the main syncline or by way of the strip of sandstone adjacent to the Douglas fault, west of Lake Superior. The known thickness of these red sediments in Minnesota is much less than that of the equivalent rocks in the Chequamegon Bay region, so that it may be that they represent only a portion of the series.

The areal connection of the Bayfield group with the lighter colored quartz sandstones of the Kettle River region appears highly probable. But the age of these rocks is unknown, since they too are barren of fossils and are separated by a fault from the traps which intervene between them and the known Cambrian of the St. Croix valley, and are separated by a drift-covered interval from all other strata of known age. A connection with the red clastic series, is, nevertheless, possible.

It therefore appears that the Bayfield group is much more closely allied to the Upper Keweenawan than to the Cambrian. Nevertheless, we must recognize the possibility that it may have been deposited in an inland basin, in part at least contemporaneously with the lower parts of the Cambrian series, and may later have merged into the marine strata when the advancing sea entered the Lake Superior basin. The slight degree of metamorphism exhibited by the Keweenawan sediments as compared with that of the older rocks of the region, supports this view. However, the overlapping of the upper Cambrian strata over the red sandstones in southeastern Minnesota appears very much like an unconformity. Such a discordance could naturally not be recognized in the churn drill records which form the only source of information regarding these deeply-buried rocks.

The equivalence of the Bayfield group with the Jacobsville sandstone ("Eastern sandstone") of Michigan cannot be proved on account of the lack of areal connection, but the lithologic likeness is complete. The Jacobsville is believed by Lane and Seaman of the Michigan Survey to be conformable beneath the light-colored sandstones (Munising) of known Cambrian age (see p. 16). The two areas of sandstones are separated by a

wide area of older rocks and may well be of widely different ages. Therefore none of the results of this study should be applied to the question of the relative ages of the Michigan formations.

The question of the relation of the Keweenawan to the Cambrian cannot be here entered upon.[1] It is sufficient to say that so far as Wisconsin is concerned, there is no reason for separating the Bayfield group from the Oronto group, the upward continuation of which it undoubtedly is. Therefore, the Bayfield group, according to all observations we could make, is of Upper Keweenawan age.

Summary of Geologic History. The Huronian formations of the western end of Lake Superior were brought substantially to their present condition before the deposition of the earliest Keweenawan sediments. Their sandstones had become indurated to quartzites, their shales largely metamorphosed to slates, while the iron formations had been greatly weathered. In Wisconsin, however, much of the deformation appears to belong to the same period as that of the Keweenawan.[2]

The first Keweenawan sediments were quartzose sandstone and conglomerate, derived from the erosion of these older rocks. After a slight thickness of this had accumulated, volcanic activity commenced. Lavas of varying types were poured out until a thickness of many thousands of feet had been built up in the structural basin now occupied by Lake Superior. Most of these flows were of basic composition, and none show the characteristics of submarine deposition. Interbedded with the igneous rocks are layers of conglomerate and sandstone, derived from the erosion of adjacent flows. These are mainly composed of debris from acid rocks, since those probably formed greater elevations than the more fluid basic varieties. In the latter part of the eruptive period, enormous masses of gabbro were intruded into the surface flows.

During the deposition of these Keweenawan igneous rocks, folding and faulting went on. In the pebbles of the Outer Con-

[1] For a fuller discussion see Van Hise, C. R., and Leith, C. K., Geology of the Lake Superior Region, Mon. U. S. G. S., vol. LII, 1911, pp. 378–415.

[2] A full statement of these facts will be found in Ibid., p. 366.

glomerate, just above the highest flow of the series, are found representatives of all the older rocks, including the deep-seated intrusives. This plainly indicates that tilting and erosion proceeded simultaneously with deposition in the lower parts of the great structural basin. Although the lowermost Keweenawan rocks now exposed were thus not subjected to the weight of all the strata stratigraphically above them, there is no reason to doubt that an enormous thickness was laid down in the middle of the Lake Superior synclinorium.

Oronto Group. Following the deposition of the lava flows, the volcanic activity ceased and sedimentary rocks alone were formed. These rocks, like those interbedded with the traps, were laid down by the streams that eroded the upturning edges of the great basin, and deposited their load upon the floor of the depression in order of the coarseness of the particles. The same process may now be seen going on in the enclosed basins of modern mountains. Whether or not standing water occupied any of the syncline, or the sea entered, is unknown; for it should be recognized that the only rocks now visible are those that were deposited near the edges.

A comparison with modern alluvial fans, shows that the grade of the depositing streams probably decreased as they left the mountains. Near the foot of the surrounding elevations, conglomerate was deposited where the streams just began to spread out and deposit the coarsest portion of their load. Farther out, the gradient lessened still more, and sands and clays were deposited on a slope of probably less than a hundred feet per mile. Floods and shifting of channels, however, mixed the various kinds of material, giving us such sharp changes as between mud and gravel. When the deposits were not covered by water, mud cracks developed and hardened sufficiently to be preserved under the next layer of sediment, which may often have been blown over them by the wind—although there is no recognizable evidence that any large dunes existed. At other times the shifting streams formed temporary lakes, in which ripple marks were formed by the waves, although many such marks appear to have been formed by currents. Again, changes in the currents eroded troughs in previously-deposited sediments. These were later filled, often with somewhat coarser material than that below.

We must, therefore, recognize that deposits of varying lithologic character were formed simultaneously, so that such formations represent not periods of deposition of different materials but the shifting of the zones of deposition, due to the filling up of the basin. The material of the higher beds was progressively more and more weathered, a fact to be correlated not only with this process of shifting zones, in which the material deposited farthest from its source was better weathered, but also with a very probable lessening in the rate of erosion and transportation, and possibly with increase of vegetation on the uplands—both factors favoring chemical decomposition.

Further, it appears quite probable that as time went on, the soft basic traps were eroded to low levels and covered more and more by the spreading sediments. Thus the older sediments, granites, and other more siliceous rocks furnished a relatively greater portion of the material brought down by the streams. It will further be seen that the sediments thus overlapped unconformably upon the previously-eroded lower slopes of the trap mountains, so that although no exposure of such a contact is known, one may yet be found; but this would not prove that the sandstone was much younger than the trap.[1] As the Douglas fault is structurally a part of the general Keweenawan deformation, it is entirely probable that along it more or less movement may have taken place throughout the time of deposition of the sediments.

Bayfield Group. No stratigraphic or sharp lithologic break occurs between the Oronto and Bayfield groups of sandstones, so that no cessation of deposition or radical change in conditions could have occurred. The further extension of the processes outlined above, brought about the change from little-weathered feldspathic sands and clays to fairly-clean quartz sands with very little clay. The greater abundance of acid trap and quartzite pebbles shows that as time went on those rocks furnished more and more material. The red coloration and peculiar bedding,

[1] It appears probable that the red clastic series of Southeastern Minnesota overlaps the traps of the center of the basin upon the granitic rocks of both sides of the basin, and gradually thins out between them and the overlying Paleozoics.

troughs, and so forth, are all found in the Bayfield group, thus indicating conditions of deposition similar to those which previously prevailed. It is unwise, however, with the present imperfect knowledge of the interpretation of different types of bedding, to attempt to state what parts of the formations are fluviatile and what subaqueous. There is little evidence that any is strictly aeolian. There is a strong probability, however, that the Devils Island sandstone differed in manner of deposition from the beds above and below. The prevailing dip of the cross-bedding indicates a northern source for the material, while the lighter color and abundant ripple marks may be indicative of a subaqueous origin. There is insufficient coarse and unweathered sediment in the neighborhood of the Douglas fault to render it certain that there was any considerable movement on that displacement, with the necessarily consequent rapid erosion, during the period of the deposition of the Bayfield group. However, as deformation continued, so that there has been over 3,000 feet of movement since that time, it is not impossible that faulting took place at intervals. The date of the latest movement cannot be ascertained; but as the lower part of the Bayfield group was involved in the Keweenawan folds, it is evident that the deformation continued at least to that time.

As no formations older than the Pleistocene overlie the Bayfield group in Wisconsin, we cannot ascertain how long sedimentation continued. Presumably the entire Lake Superior basin was filled up, thus checking the erosion of the surrounding highlands. Whether or not the deposition of the Bayfield group merged into the Cambrian, when the sea invaded the continent, is unknown. The entire Lake Superior region was doubtless covered by Paleozoic sediments, which have since been almost wholly worn away. It may thus be seen that the basin of the present lake, as distinct from the structural basin of the Keweenawan rocks, does not differ essentially in origin from the basins of the other Great Lakes (see p. 95).

Summary of Conclusions. The Bayfield group of sandstones is conformable upon the recognized Upper Keweenawan sediments, and is therefore a part of that series.

The contact of the Bayfield group with the Middle Keweenawan traps is along a thrust fault, on which great movement has

taken place since the deposition of the sandstones. It is probable, however, that as this fault is to be correlated with folding in which the Bayfield group participated, that some movement took place during its deposition; but that such unconformity if it exists, does not represent any considerable lapse of time.

Folding and probably faulting went on contemporaneously with the deposition of both the Oronto and Bayfield groups. The sediments accumulated in the sinking middle portion of the great Lake Superior syncline, while the edges were being relatively upraised and eroded. As the sediments accumulated, they overlapped unconformably upon the feet of the surrounding elevations. Such unconformable contacts have been largely eroded away, but may yet be found. The relation of the sandstones to the traps at Duluth may be of this character, but is probably complicated by faulting.

Both the Oronto and Bayfield groups of sediments are largely if not wholly of non-marine origin, having been laid down by streams in an enclosed basin, not necessarily, although very likely, under desert conditions and probably in part under standing water. The climatic conditions were favorable to the oxidation of iron, a fact denoting a scarcity of vegetation.

The age of the Bayfield group cannot be determined without determining the relation to the Cambrian of the Mississippi valley, with which no areal connection is definitely known. It is possible that non-marine deposits in the Lake Superior basin may have merged into the marine deposition of the Cambrian sea.

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